A KEY

TO THE

ELECTROCARDIOGRAM

BY

LOUIS FAUGERES BISHOP

A KEY

TO THE

ELECTROCARDIOGRAM

BY

LOUIS FAUGERES BISHOP, M.A., M.D., Sc.D., F.A.C.P.

PROFESSOR OF THE HEART AND CIRCULATORY DISEASES, FORDHAM UNIVERSITY; SCHOOL OF MEDICINE, NEW YORK CITY; CONSULTING CARDIOLOGIST TO THE LINCOLN HOSPITAL; FELLOW OF THE NEW YORK ACADEMY OF MEDICINE; MEMBER OF THE AMERICAN MEDICAL ASSOCIATION, OF THE MEDICAL VETERANS OF THE WORLD WAR, OF THE AMERICAN THERAPEUTIC SOCIETY, OF THE NEW YORK PATHOLOGICAL SOCIETY, OF THE SOCIETY FOR THE PREVENTION AND RELIEF OF HEART DISEASE, AND OF THE ALUMNI ASSOCIATION, ST. LUKE'S HOSPITAL; AUTHOR OF "ARTERIOSCLEROSIS" "HEART DISEASE BLOOD PRESSURE AND THE NANHEIM TREATMENT." AND "HEART TROUBLES, THEIR PREVENTION AND RELIEF."

ILLUSTRATED

NEW YORK

WILLIAM WOOD COMPANY

MDCCCCXXIII

PRINTED IN THE UNITED STATES OF AMERICA

Press of
Hamilton Printing Company
Albany, N. Y., U. S. A.

PREFACE

The electrocardiogram has raised the treatment of disorders of the heart from a speculative undertaking to one founded on a very definite plan of procedure. A great student of the heart is said to have remarked in a comparatively recent lecture that the invention of the stethoscope held back progress in cardiology fifty years. His meaning was, that undue reliance upon interpretation of abnormal sounds of the heart has given a false sense of knowledge which has resulted in many errors.

Auscultation is, of course, valuable in the detection of regurgitation through incompetent valves and on some occasions in the detection of narowed valvular orifices. In the latter instance, however, the inference is as apt to be incorrect as correct. So long as no other method was available, it was absolutely right for physicians to cultivate their powers of auscultation to the last degree, but now that new and much better methods have been discovered and perfected, they should be adopted promptly.

I will try to impress the advantage of electrocardiography over ausculation by a homely comparison.

The heart is shut up in the chest and is therefore not subject to inspection. In like manner a frog may be shut up in a box. Now suppose four wise men were seated around this box with the frog inside, and each, with his ear close to the box, was listening to the frog to see if he could determine which legs the frog was moving or what he was doing.

One wise man might say: "I hear a scratching sound and I believe the frog has moved his right front leg;" another might venture: "I heard a loud thud and I am sure the frog has kicked his left hind leg," and the third man might assert that he heard a general scratching and pounding sound and believed the frog was moving all four legs. After retiring to an adjoining room for an hour or more to debate and discuss the matter of which legs the frog moved, the wise men would have

reached no definite conclusion as to just what the frog had been doing in the box.

Now suppose these same men returned to the room, where the frog was shut up in the box and attached a piece of string to each of the frog's legs, and, after labeling the strings as to which leg each was tied to, they hung the strings outside the box. They could now determine by watching the strings just exactly what the frog was doing with his limbs.

Later on, assume they discovered that each time the frog moved a limb the contraction of that muscle generated a current of electricity of a type peculiar to that particular limb. If a wire was attached to the frog and if the little electric currents which were generated when the limbs moved were collected, it would be possible, by studying these currents to find out which muscles the frog was using when he moved his limbs. If we substitute the human heart for the frog these things which have just been mentioned have actually been accomplished. Each muscle bundle of the heart as it contracts, generates its own particular electric current. These currents are collected by wires attached to the limbs of the person under examination, and the currents are sorted out and studied by passing them through a fine filament between the poles of a powerful magnet. The filament sways back and forth according to the quality of the current passing through it. The shadow of the string is photographed on a moving film, and when printed, an exact picture of the activity of the heart under examination is obtained.

This in simple terms is electrocardiography, a painfully long name for what is in reality, a very simple matter. It is hard to believe that so simple and wonderful a method of studying the heart action has been so long in reaching the whole medical profession and in being put to general practical use.

It is a fact that many hundreds of people are relieved every year through the knowledge of their condition which is obtained by means of the electrocardiograph. It has made many previously fatal disorders of the heart perfectly clear and daily enables a positive distinction to be made between serious and innocent heart troubles.

This book is in part, an expansion of papers which were read at various times before groups of specialists and general practi-

tioners. The possible usefulness of a book of this character, containing in simple form the rudiments of the subject and omitting all matters of controversy and rare cases, was suggested by the comments of a number of these men who were kind enough to tell me later that they dated their interest in Cardiology from the time of my paper.

I think it was Huxley who said that he had frequently been accused of a lack of technical knowledge of his subject when he had attempted to present it in very simple terms. It is true, indeed, that a presentation in allegorical form puts one at the mercy of a certain class of critics who are educated beyond their intelligence, but this is more than counterbalanced by the approval of the average reader when supplying him with an easy grade, up which to climb the first steps to what must, of necessity be a very difficult subject.

I would be ungrateful indeed if I did not express my appreciation of the help rendered me by my associates and by the publishers in preparing this little book.

109 E. 61st St. Louis F. Bishop
New York.

CONTENTS

A Key to the Electrocardiogram

CHAPTER I

USE OF GRAPHIC METHODS AND HISTORY OF THE ELECTROCARDIOGRAPH

The average physician, on seeing the electrocardiogram of a person for the first time, is apt to avoid giving it any attention, just as he would refrain from spending time in gazing at the letters of the alphabet of a strange tongue. He is satisfied that the tracing bears significance for the initiated, just as the unknown symbols hold a meaning for those who are accustomed to speak the language they represent, but, for his part, he feels that he must content himself with more familiar matters and leave hieroglyphics for those who are expert in deciphering them, so he turns over the pages on which they are inscribed and has to take for granted whatever he is told as to their signification.

This is the impression that I have received time and again when attempting to lecture to a medical audience on the use of the graphic methods of electrocardiography, and it has struck me that the reason is that a great many workers have not grasped what a graphic method really is and how its terms may be applied in many different branches of learning and practice. In other words, the graphic method is not so much a distinct language which, like Chaldean bricks can only be painfully picked out by the savant, but it is a sort of easy universal key, a sign writing, in which all tongues can be read, and all kinds of activity described in such a form that he who runs may read.

Any method of attempting to suggest the motion of something which moves, by means of a picture or wavy line, is so elementary that it is probably as old as the human race, or as old as that portion of it which endeavored to convey its ideas by signs, and that is very old indeed. The immense conception of the zodiac, a line which first rises above and then dips below the celestial equator, and is dotted with twelve constellations

in which the sun appears to sojourn, one after another, in its course, is nothing but a primitive attempt of the mind of man to chart the movements and the time element of celestial phenomena; and the amount of genuine observation given to the planetary motions in times before the dawn of science, should stimulate us in modern days to an equal amount of alert attention in recording scientific phenomena.

Modern industry owes its unparalleled growth to the fact that is has harnessed to its use all the discoveries, devices, and methods which science can achieve. The great pioneer industrial firms rely on the findings of research laboratories, which they maintain solely for the purpose of working out secrets of eliminating waste and furthering progress. When they try out a new method they want to find out what its results are; when they employ a large number of workmen they want to measure and appraise exactly what the output of labor is. In other words, a "record of performance" is needed, and to obtain this, graphic instruments are installed, equipped with electrical meters which give a precise charting from hour to hour and from day to day of the amount actually achieved. If the result falls short of what it should be the record shows the weak spots upon which attention should be concentrated. The meter cannot cure the symptoms, but it can read the pulse, and it is for the specialist in industry, as it is for his brother in medicine, to prescribe the treatment. An everyday example of the application of such a graphic method in dealing with the vitality of an industrial pulse is shown in the following manner. In a large manufacturing corporation which made use of a system of electrically driven motors it was noted that there was a daily lag in output so that the products were less in quantity than they should be. A graphic instrument, put to work, recorded a lag in output every morning when the workmen came in and started their work. It took an hour for them to get the motors running full speed; again at noon in anticipation of the lunch hour, the workmen fell off in their efforts; in the same way they slackened down before closing time. When the cause of the diminished output was "placed" and recorded on the chart at the time of its occurrence, it was an easy matter to correct it.

When we come to the use of the graphic chart in medicine, one of the simplest and most commonly used is the temperature chart. True, it is traced by hand from day to day, and not from one fraction to another by an electrical instrument, as is the case with the electrocardiograph, but none the less the analogy is not a very distant one. Both charts have a time factor and a "record of performance" in relation to the time charted. The temperature chart expresses a picture of the body's combustion processes; a steady, moderate flame in health, a raging furnace in conditions which are wasting the body's resources, and a dull ember in enfeebled and senile conditions. The temperature chart is so characteristic of the balance of the patient's forces that the first thing a physician does when called to the bedside is to examine it and see what its sign language spells for him. Certain types of ups and downs mean a definite thing to his mind as he has been taught by long experience to associate a particular appearance of the line with a certain pathological condition, and a glance at the "sign writing" gives him an insight into the sufferer's illness.

The use of the hand-traced graphic chart is so common in all branches of medicine and allied sciences that it is only necessary to mention such different instances as the weight and feeding charts for infants; percentage curves showing relation of suicide or of insanity to economic stress, and the striking charts with the towering rise and gradual decline by which epidemiologists trace the successive waves of epidemics, to appreciate the readiness with which this type of symbolism may be applied in all fields of observation.

When we come to the use of the graphic chart in electrocardiography, we have a system which is very much akin to that used by engineers in making an estimation of an electric motor, or of the conditions and output of a power station. In such graphs the various factors of voltage, power, load, friction, or interruption to service are taken into account. Tests are made with the motors under load so that any possible detrimental factors may be determined and shown up in the chart.

The study of the heart is literally one of a very complicated motor and one which was designed to conform with very extraordinary specifications. When we consider that it is one which has to be confined within a very small space; that it must be

quiet, frictionless, self-starting, and self-adjusting, so that it may respond instantly to calls for heavier work and yet be capable of slackening down when the demand is lessened; that it must furnish its own repair material and apply repairs without for a moment stopping the machinery or becoming disconnected from the load; that it must be in order and working day and night for the whole lifetime of a man, sometimes as long as one hundred years; we can see that it is a machine which far surpasses the most powerful and complex which has ever been designed by man. Is it any wonder then that the records of such complex activity are very striking and yet somewhat difficult to interpret? Compared with the variations which mark a chart for the study of the electrical engineer, they must present a number of factors of which he does not have to take any account. The instruments of precision which trace the phenomena of the heart's activity must also be of extreme delicacy in order to trace graphically the electrical discharges which are generated in the human motor itself. The sign language of electrocardiography while very striking, therefore, is more or less difficult, and its final interpretation has by no means been made, although to the expert student of these charts, as to the physician who estimates a disease from the look of the temperature chart, there are certain characteristic tracings which give a clue to the sufferer's symptoms. Let it be emphasized, however, that interpretation of the tracings is to be fortified by long experience, and the whole clinical picture of a man must be taken into consideration when studying his electrocardiogram.

The profession is always seeking for rule of thumb methods by which a certain diagnosis can be declared, because a patient showed such and such a sign. McBurney's point in appendicitis is a favorite of long standing, although there are some detractors who claim that a man must know something else about the patient before he diagnoses acute appendicitis and advises an operation. It must be acknowledged that in electrocardiography such plainly marked signals have not yet been developed, and I do not believe that they ever will be, because clinical knowledge, imagination, and experience have always to be put into the balance when judging the relation of the electrocardiogram to a man's condition.

When we come to search for the commencement of the ideas that led to the development of modern cardiography, we find that, like many famous persons and well known discoveries, it has had its origin in very lowly circumstances. A humble happening observed by a man of genius, however, often gives rise to conclusions which transform the thought of the world. The apple which plumped down beside recumbent Newton is an example. "Relativity" may have been suggested by seeing a pup chase its own tail. The conception of electrocardiography really took place when Galvani, early in the 18th century, made the simple observation that frogs' legs could be moved by the discharge of a small amount of electricity which he had accumulated in a small storage battery. So direct is the relationship of the modern instrument to this discovery that it is acknowledged in the phrase "string galvanometer," a term very often used to describe the electrocardiograph. Galvani was able, by a very simple experiment, to show the connection between muscular activity and electricity. Literally, he made the frog's legs jump, without the frog. He hung frog's legs on an iron railing, so that one end of the muscles was well grounded, and allowed the spark to escape into the legs, which thereupon gave a violent and life-like jerk. This very clearly showed that the "kick" in the frog's leg may be caused by electrical currents. Furthermore, all muscle when it contracts produces a current of its own.

At a very much later day in the history of science, Dubois-Raymond found that electrical currents from the outside were not the only evidence of electricity in muscular contraction, but that the very action of contraction itself generated a minute electrical current. This current is caused because all parts of the muscle do not contract at the same time and the current flows from the contracted to the relaxed fibers. Such a current is generated by the motion of the muscle in the same way as the electricity of the self-starter of an automobile is generated when the car is running. Thus, currents are continually manufactured in the body by muscle contractions and even by secreting cells. For that matter, all tissue cells in their very process of living produce electrical currents through transformations which are always taking place.

These discoveries are all due to the perfection of instruments

capable of detecting such minute changes. The galvanometer, of which countless models have been constructed, is the most important by far. It is capable of detecting and measuring electric currents and it is a specialized modification of this common instrument, attained after years of study and research, that enables the physician to diagnose accurately and treat his suffering heart patients. In view of the fact that such a large percentage of chronic afflictions is due to cardiac disorders, this instrument, namely the electrocardiograph, is becoming one of the common diagnostic measures of modern medicine.

The principle of this perfected machine depends upon the fact that if a current is passed through a wire which is placed between two poles of a magnet, the wire will be deflected one way or the other, according to the direction of the current passing through it. The currents, in this case, are generated by the heart. As this organ goes through a series of contractions the currents which produce the waves in the wire are measured by the size and duration of the waves, and recorded on a chart ruled both horizontally and vertically for that purpose, which will be explained in detail later on.

Since the heart lies obliquely in the body the distribution of the currents given off is not symmetrical, but is always recorded from the arms and left leg. From here, wires lead to the string of the galvanometer, between the magnets. The wires carry the heart currents and the currents deflect the wire. The two wires at any time leading to the string of the instrument are called "a Lead."

The question is often asked as to why, in making electrocardiographic tracings, the wires are attached to both arms and to only the left leg. The reason for this is that the apex of the heart points toward the left in regard to the trunk, so that the best lines for observation of the differences of potential are:

(1) across the top of the heart, between the two arms;

(2) the axis of the heart, beween the right arm and left leg;

(3) the left side of the heart, between the left arm and left leg.

If the right leg were used the line between the right arm and right leg would not cross the heart at all, neither would an observation from a line taken from one leg to the other directly cross the heart. In those rare cases of transposition of viscera

where the heart points to the right, we naturally take our observations with leads which correspond to the altered position.*

Another inquiry which is often made is why it is necessary to have three leads, and in what way the leads differ. It should be stated that different parts of the heart attain different degrees of potential during the beat. The leads are as follows:

Lead I............. Current from right arm and left arm;
Lead II............. Current from right arm and left leg;
Lead III............. Current from left arm and left leg.

In the normal individual the three leads have somewhat different values. There is, however, a considerable latitude of variation in the waves of all the leads without going outside the limits of the normal, so that we can repeat that no hard and fast rule can be laid down as to what is a "normal" electrocardiogram. The curve must be normal for the individual when all clinical data are duly considered.

In regard to the heart currents which are carried by the leads to the galvanometer, one must realize that they are extremely minute and that the wire which is sensitive to them must be of extreme delicacy. It is so fine, indeed, that it can scarcely be seen by the naked eye and measures barely the width of a red blood corpuscle. It is, however, so sturdy and flexible that it may readily be adjusted by means of infinitely larger electric currents than those generated by the heart. Thus the sensitiveness of the string can be tested at any given moment. This can be varied by increasing or lessening the tension of the wire by means of a micrometer screw. It is usual so to adjust the string that a passage of one millivolt of current makes a deflection of one centimeter in the shadow. The movements of the string are photographed on a revolving film, which, when developed, gives us an electrocardiogram, or, in other words, a true heart autograph.

In general it may be said that observations of the electric currents collected across the top of the heart are more affected by the activities of the upper pole of the heart (Lead I); that the observations taken in the axis of the heart (Lead II) are indicative of the general activity of the heart as a whole; and that the observations taken of the left side of the heart (Lead III) are essentially influenced by the left ventricle. This is well

* Dextrocardia causes inversion of all waves in Lead I, including P.

FIG.—1.—Diagram illustrating the origin in the heart of the three currents giving rise to the three Leads of the electrocardiogram.

illustrated by the difference easily noted in the leads, in that the upper pole gives the upward R wave; observation of the axis of the heart gives a lower R wave; and when the left ventricle is enlarged the tracing of the left side of the heart gives a downward wave (S).

A thing which is very hard to understand is that electrocardiographic tracings are really a record of the variations in potential between various parts of the heart. There is probably no particular current flowing along in the direction in which we measure it, but when we connect different parts of the heart which have a different potential, current does flow. The activities of the heart create differences of electric potential in different places and we observe them and interpret them as best we can. This explains definitely why we are able to measure the relative activity of different chambers of the heart, such as the right and left ventricles, when we refer the activities to a standard set of leads.

Since the time when the electrocardiograph was first worked out by Adler in 1897, and later perfected by Einthoven, many refinements of the instrument have taken place. One of the earliest was the discovery, by Einthoven himself, that the heart's currents may be carried through wires for a long distance. In his laboratory at Leyden electrocardiograms were made on patients in a hospital a mile or more away. This revelation has made the use of the electrocardiograph eminently practical in hospitals where ward beds can be wired and the heart action of patients lying in their ward beds be recorded in the electrocardiographic room.

A device was used by Siemans and Halske wherein a coil, with a minute mirror attached, was used between the poles of the magnet instead of a straight filament. The heart currents caused a rotation of the mirror to one side or the other and a reflected beam of light was recorded as a result. This instrument is not used in this country, but it is preferred by many foreign investigators because the coil does not require as delicate adjustment as the filament.

On the same principle as the electrocardiograph it was found that vibrations caused by the heart's sounds could likewise be electrically recorded. Therefore, two wires, one for the heart action and one for the heart sound, may be inserted between the

magnetic poles and a picture of each recorded. Although such photographs are very valuable in some instances, it requires careful and expert manipulation to keep the strings independent of each other.

Many ingenious devices have, from time to time, been used along with the electrocardiograph, such as the photograph of the blood pressure measurements and the respiratory rate and size of excursions. The possibility of other devices and refinements is endless. Recently an article appeared in a popular scientific paper in which this machine was proposed to make records in the detection of crime.

In the electrocardiograph, therefore, the heart writes its own story, and thus, indirectly the story of the whole body. As a result electro-medical science has attained an undreamed of state of exactitude, the glory of which is that this instrument is not a mere delicate plaything of the laboratory investigator but a hard worked, everyday tool of the modern clinician.

A final word of caution must be added against an over confidence in complete diagnosis by means of the electrocardiogram. Like a great many other expert laboratory tests, it does not replace clinical examination, and should be used only to verify and corroborate a careful general observation of the patient. There are many obscure heart conditions in which the diagnosis would remain in doubt without the employment of the electrocardiograph. It should be taken on several successive occasions and under different conditions, in order to eliminate any possible errors due to extraneous influences. The disturbances produced by nervousness, fatigue, and exertion can thus be given their due value in estimating the patient's general condition. Used thus, carefully and methodically, the electrocardiogram is a record of great precision and diagnostic value in the recording of cardiac disturbances or alterations.

In concluding this chapter I would like to quote what Dr. John Hay says in this connection: In his book entitled "Graphic Methods in Heart Disease" he deals with the question of the practical value of cardiography to the average physician. He says "I can imagine a practitioner asking how the investigation of the action of the heart by these methods can be helpful to him in his practice. The answer is that it creates a new interest. His knowledge of the heart becomes more concise.

He is no longer satisfied with a sloppy diagnosis such as 'irregular action of the heart,' but is able to define clearly the nature of the irregularity. He is constantly checking and correcting his diagnoses based on the ordinary clinical examination.

"As his diagnosis becomes more correct, there is a corresponding clarity in his prognosis. He speaks of the future with more confidence. The various deviations from the normal are appreciated at their proper value. He no longer penalises an applicant for insurance because of an occasional extra-systole, nor does he blight a boy's school life because of a sinus arrhythmia. An extra-systole which unmasks an alternating pulse is to him full of grave significance, for he recognizes that it may be the first indication of impending disaster. His mind ceases to be a hazy fog in regard to auricular fibrillation. Every day he is dealing with this serious complication of the disabled heart, and gradually he acquires an accurate knowledge of the diagnosis, prognosis, and treatment. Heart-block ceases to be a mystery, and he welcomes the opportunity of analyzing a case of rapid heart action.

"He learns when it is essential that the ordinary methods of clinical investigation should be supplemented with the information which can only be supplied by the polygraph or electrocardiograph. And he will gradually find that he becomes less and less dependent on these instruments with which he has served an apprenticeship, for he has educated himself to do without them. His fingers, his eyes, and his ears are enough in themselves. He has made an advance as a clinician."

Thus the only proper qualification for the practice of cardiology without instruments of precision is a long use of them. But the man who has gotten to know them never willingly gives them up.

CHAPTER II

THE ELECTRIC AUTOGRAPH OF THE HEART OF A HEALTHY PERSON

It should be remembered that the electrocardiogram is an autograph and that, like the autograph of a person, it always differs from the autograph of every other person. This does not mean, however, that the autograph of an average normal individual cannot be told from that of an ignorant, illiterate or very aged person.

To understand the normal electric autograph it is necessary to comprehend the true nature of the heart beat. The heart beat and the heart sounds do not correspond because some of the most important events in the heart do not make any noise and some of the least important give loud sounds.

The two sounds of the heart are caused by the thud of the ventricle when it begins to contract and the closure of the aortic valves when it begins to expand. The auricle makes no sound and after the heart suddenly begins to contract the ventricle makes no further noise.

However, every activity of the heart is recorded in the electrocardiogram as it happens. The heart action is found to divide itself into three principal parts:

(1) The auricles contract (P wave), and gently push the blood into the ventricles.

(2) The mitral and tricuspid valves close; the ventricles contract firmly, suddenly opening the aortic valve, and take a grip on the blood contained in the ventricle (R wave).

(3) The ventricles proceed to squeeze the blood out of the heart into the pulmonary artery and aorta (T wave).

When the ventricle takes its sudden grip on its contents a sharp electric current is generated. This is recorded in the electrocardiogram as the R wave. The reason that this is a sharp, intense current is due to the fact that fluid cannot be moved suddenly. If you have ever jumped from a high place and landed flat on the water you have discovered this fact.

A little later the water moved and you sank; but at the moment of contact the water did not feel as if it were going to move.

When the ventricle has contracted on its contents, it proceeds to perform its real work in a much more gradual way and to squeeze the blood into the circulation. This work of the ventricle is recorded by the T wave. Therefore, just as a person in signing his name writes his given name first, then his middle name and finally his surname, the heart, through its electric current, writes in the electrocardiogram its P, R, and T—its auricular and ventricular activities, and its ventricular contraction.

The waves of the electrocardiogram are denoted in an arbitrary manner by certain letters. It was decided to take a series of letters at the end of the alphabet, namely, P, Q, R, S, T, U, to represent certain waves found in the electrocardiogram.

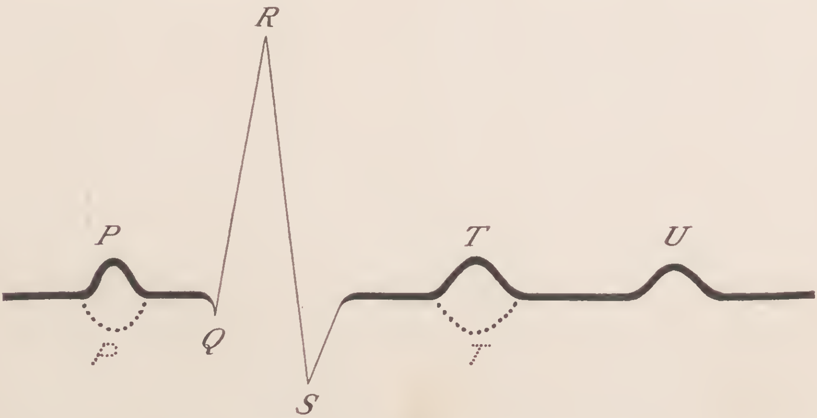

Fig. 2.—Scheme of the normal electrocardiogram.

These letters cover all the large and small currents that can occur in the electrocardiogram of all healthy people. Some persons write their names on the line, others above, and then again some write below the line. In the same manner some electrocardiograms have the Q waves (between the P wave and the R wave) going below the line, and the S wave (between the R wave and the T wave) also below the line. Occasionally there is a U wave after the T wave—a final flourish, as it were.

I have spoken above of the normal electrocardiogram. This is a statement which I must not let pass without some qualification, because if I were to speak to you about a person with a

"normal face" you would burst out laughing and say "Doctor, what do you mean by a normal face?" The fact is that there are as many varieties of faces as there are of inhabitants on the globe, and there are racial variations as well as individual ones, so that what is a normal face for a Chinaman may be strikingly unusual in one of New York's four hundred. The same may be said of the manifold variations of electrocardiograms. The question is whether the electrocardiogram is normal for an individual in all his relations, and for this reason this expression of the heart's activities is never a complete interpretation, but only a relative one, which must be considered with all the other factors of a person's physical and mental make-up.

Before passing on to the consideration of variations which are frequently seen in association with distinctly abnormal conditions, let us recapitulate the knowledge we have acquired as to the titles of the waves and what they represent. To borrow a phrase from our old friend Euclid let us say "Let P be the activity of the auricle."

SCHEMA OF WAVES

P up or down,
Q always down,
R always up,
S always down,
T up or down.

The base line is the shadow of the string when no electricity is passing through it.

When electricity is passing through the string, that is when the excitation impulse is being recorded as it passes in its due course from one portion of the heart to the other:

First

The auricle contracts (auricular systole) and makes the P wave	which is usually a little mound above the base line, sometimes a cup below it. It can be up or down.

Second

The ventricle becomes active; sometimes it causes the Q wave	a little downward dip, not always seen, but when present leading up to

Third

The chief activity of the ventricle, represented by the R wave	which makes a church steeple-like wave, always above the line, then

Fourth

The wall of the steeple plunges below the base line again and makes the S wave	always below the line, and sometimes this S wave is all of the ventricular activity shown, then comes

Fifth

the curve which represents the final activity of the ventricle, and is called the T wave	this may be either up or down.

Finally

there is occasionally the U wave	this pertains to diastole.

From T to the following P is the diastolic period.

When there is a long steeple-like wave below the line, it is not a reversed R wave but an exaggerated S wave, the R wave at the same time being stunted.

It may be stated here that the minor waves are of very little significance in studying the electric autograph. Almost all the advantage of the study is obtained from the P, R, and T waves. In a healthy person the beat of the heart commences in the auricle which contracts, and pushes the blood into the ventricle. The ventricle contracts sharply on the blood contained in it and further contracts more slowly to drive the blood into the circulation. These events come regularly in sequence and are recorded by the P, R, and T waves.

When we have clearly grasped the various letters of which the autograph is composed, let us turn to the grouping and see if we cannot read the message and signature of the heart as it is inscribed. In other words, the curves are written for us, what can we make of them? We shall do very much better if we proceed to spell them out syllable by syllable in an orderly manner.

The Significance of the Downward T Wave. In describing the waves, it has been stated that the P wave may be up or down, that the R wave is always up, because when it appears to go down, it is another thing, being the S wave. But the T wave,

like the P wave may be up or down. Downward T wave has a special significance, particularly when it occurs in the first or second leads, and parenthetically it may be remarked that the downward T wave constitutes a variation in the electrocardiogram that can never be overlooked or made light of. In the

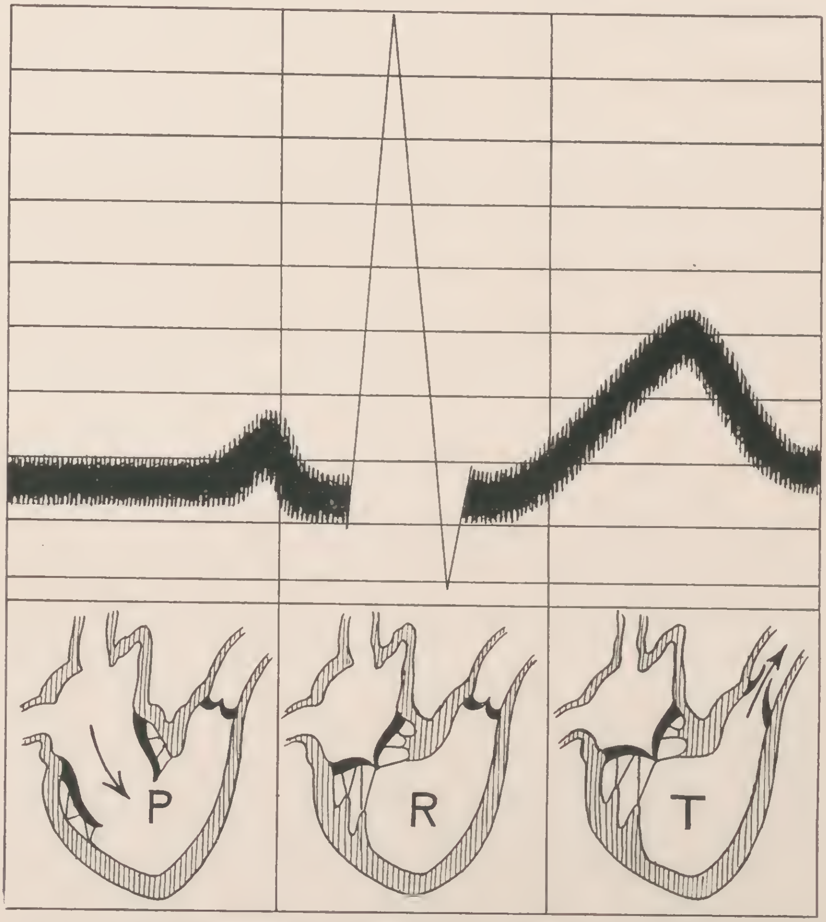

FIG. 3.—Diagram illustrating the heart action shown by the three principal waves (P, R, and T). P represents the contraction of the auricles, R the first sharp contraction of the ventricle, and T the further slower contraction of the ventricle driving the blood into the circulation.

same way an abnormal Q, R, S complex is always entitled to very careful consideration.

The person with a downward T wave in the first and second leads is one requiring a most careful treatment and is subject

to serious heart attacks. On the other hand the absence of the downward T wave is not a guarantee of the integrity of the heart; so the sign is a positive and not a negative one.

It must always be remembered that a negative T wave in Lead III is common in healthy hearts and also that a downward T wave in people who have taken digitalis within a few weeks may be due to that.

The downward T wave in the first lead is often seen in the hearts of people suffering from angina pectoris and aortic valvular disease. The downward T waves in the first and second leads are very frequent indeed in people who carry a very high blood pressure. Here the condition is one of over-work of the heart. The downward T wave in Lead II and not in Lead I is not as serious an indication as when it occurs in Lead I or in Leads I and II, but nevertheless it is found in very much the same type of condition when it does occur. As the T wave is normally negative in Lead III in many people it can be disregarded and the examples where the three leads show the T wave downward, are considered of the same significance as when only Leads I and II are involved.

The negative T wave is not necessarily evidence of change in the heart tissue but it does prove the presence of functional change and it is a strong indication for careful treatment and continuous observation.

When the abnormal downward T wave is found in combination with partial or complete heart block it adds to the importance of the condition.

In studying the tracings produced we can take in order the following points: First, *the heart beat,* in regard to its rate and regularity or irregularity. Regularity of the heart is shown by even spacing of the distance between successive R waves. If these spaces are unequal, irregularity of the heart beat is evidenced. Second, *the heart rate.* The chart is marked by vertical lines, or abscissae, which measure the events of the cardiac cycle in regard to time. To procure the heart rate count 30 abscissae, representing 1/5 second each, and multiply the number of cycles (complete beats) in that space by 10. If there is part of a cycle over, reduce it to fifths of a cycle and add it to the result; *e. g.* $6\frac{2}{5} = 62$.

The reading of the leads is the next step to be achieved. As we have said, Lead II is first in importance in the information it conveys, but a comparison of the other leads is also necessary. In reading Lead II the deviations and sequence of the waves are to be noted: (1) the P-R-T sequence; is this normal? (2) the P wave; is this disturbed? (3) the P-R interval; what is its length, and is the length regular? (4) the R wave, note any distortions; (5) the T wave; is it up or down?

After careful examination of Lead II a comparison of all three leads is to be made. In examining all three leads as a whole, a low amplitude of the waves sometimes expresses a low state of contraction impulse. This must be watched for. The preponderance of one ventricle or the other can be diagnosed by comparison of the leads. In left ventricular preponderance the tall R waves, or steeples, tend to turn away from each other in Lead I and Lead III; and this is also the case in right bundle-branch-block. The latter however, shows a wide R, followed by a curve in two directions. The opposite condition obtains in right ventricular preponderance and in left bundle-branch-block. In these cases the steeples tend to lean towards each other in Leads I and III.

It would be well here to refer to the method of ruling and taking measurements in the electrocardiographic chart. Briefly it may be described as a checkerboard ruling of fine lines across which travels the wavy shadow of the string, in a general horizontal direction. Both the vertical and the horizontal ruling have their significance. The horizontal lines, or ordinates, are engraved on the camera lens. These lines represent millivolts, and the force of the wave as it rises up to a certain height, or plunges to a certain depth, is called its amplitude. Each ruled space represents 0.1 millivolt.

The Time Record: A set of vertical lines crosses the chart, by which time is measured. These are called abscissae. Each space equals 0.04 second. Every fifth line is usually thicker and occurs each 0.20 (1/5) second. These lines are caused by the shadows of regularly revolving spokes, photographed on the record.

The String: Upon this crosswise ruling of lines lies the heavy line caused by the shadow of the string, horizontal when

at rest, and taking wave forms when agitated by electric currents.

Normal Limits of Waves: Each typical heart wave has its normal amplitude and normal width (time). If this is transcended it indicates either exaggerated or delayed activity at some point in the heart.

	Height.	Width.
P wave normally	up to 2 mm.	0.08 second
P-R interval		0.12 to 0.18 second
Q (when present)	about 2 mm.	
R wave	10 to 20 mm.	0.1 second
S (when present)	2 to 4 mm.	
T wave	2 to 4 mm.	

We have now studied the plan of ruling of the chart and examined in detail the kinds of waves to be found upon it and the order in which they may be expected to occur, also the direction up and down, the height of the climb or depth of the drop, and the duration of the wave on the string. An approximate normal has been given for these factors, although it must never be forgotten that there is a considerable variation in electrocardiograms without our being able to say that they lie outside of the domain of the normal. Respiration, exertion, and the position of the heart in the thoracic cavity all have a modifying influence.

When we come, however, to the study of autographs of disordered hearts, very striking peculiarities will be seen which could not in any way be recognized as a normal mode of signature. It is well to examine these tracings with as much caution as the cashier in a bank peruses a client's signature on a check, when it has suddenly undergone an alteration which makes it look unfamiliar. It is the same, yet not the same, and he is puzzled as to its authenticity. Let us suppose that a well known business man who has been accustomed to signing a number of important checks, and having them honored by the bank, is suddenly bereft of reason, and his handwriting undergoes some eccentric changes. The checks begin to pass to the bank and the cashier is astounded to see the well known signature of John Smith written with the J upside down and the S turned the wrong way. He realizes at once that something very unusual has occurred and dares not pass the check

without consulting the manager. The chief has just received word that John Smith has been removed to a sanitarium, suffering from nervous breakdown from overwork, and that his financial dealings are not to be considered reliable. The peculiarity of the situation is thus explained and the bank is absolved from responsibility.

In the same way eccentricities will be shown when electric autographs of disordered hearts are examined, and among the first things discovered will be the fact that certain hearts show a long, sharp wave resembling the R wave, but it dives below the line in the opposite direction. This wave is not preceded by any small wave, as is found in the natural heart beat to represent the contraction of the auricle; but it comes at a time when the heart is supposed to be resting and nothing should occur. The question is: Why is this wave in the opposite direction to the natural wave of the same shape that we have become accustomed to as a natural part of the picture? The answer is that ordinary conditions have become reversed. Usually the muscles begin to contract at one end and the contraction wave travels along the muscle till it reaches the other end, and as it does so it generates a current in the opposite direction. The normal thing is for the wave of contraction to commence in the top of the ventricle and travel toward the point of the heart, and this activity produces an electric current which causes a wave above the line. When, however, the wave of contraction starts near the apex of the ventricle and travels toward its base, it produces a current in what we might call the wrong direction. There is no evidence that the beat started in the auricle before it reached the ventricle. In fact it did not commence in the auricle. The ventricle has, as it were, like the Irishman who was "agin the government" started a régime of its own, an independent performance which was entirely out of order. This tendency on the part of some portion of the heart to start somewhat anarchistic activities can be detected by studying the shape and direction of the waves. The writing will betray the fact that there is disunion of action in various parts of the heart and this is the first sign of the "kingdom divided against itself."

In proceeding with the study a means will be discovered whereby one can determine in which ventricle such an extra

beat originated and exactly what its relation is to the normal activity of the heart. Sometimes it is only an extra undertaking that does not influence the regular beats at all, but ordinarily it uses up so much of the energy of the heart that one of the natural beats is omitted.

Fifty years ago a great student of the heart predicted that when the function of the auricle was once thoroughly understood the greatest advance in the knowledge of cardiology of the century would be accomplished. This man was very farseeing and his prophecy has been fulfilled in the achievements of electrocardiography, the greatest of which is the interpretation of the relation of the auricle to the heart beat. In the older text-books of the heart the auricle is seldom mentioned. Its significance was not realized. In modern cardiology, as we are now studying it, the auricular activity is a very important element in explaining heart disorders.

An ordered sequence of events in the heart beat is perhaps the most important factor in the promotion of harmonious and efficient activity of the organ. The heart has a responsibility which can be likened to that of a ship carrying a number of passengers. When we think what the heart has to do for the safety and preservation of all the other organs—the respiratory, the nervous, the alimentary, and those of locomotion—to steer them safely on their life voyage, as it were, we can see that there must be a very efficiently directed service to maintain the welfare of such a cargo. The captain has to take charge, but he cannot do the work of the ship himself, so his orders travel to those next in command, and on down the line, each subordinate receiving his instructions, executing his part of the work, and passing on the word which directs the next man in his task. When all are working in harmony, every man in his own place, all is well, but if the officers become at variance with the captain and take upon themselves an independent authority, some of the crew perhaps go with them, some with the captain, or some set up a lawless free lance government of their own. Dire confusion results, and one wonders how, under such conditions the ship makes port. Try to imagine the heart as sailing under regular orders which best promote its safety and efficiency.

The heart beat should begin in the auricle in a regular con-

traction occurring about seventy-two times a minute and should spread in an orderly manner to the ventricles. If there is any pathological departure from the normal routine it may be shown in the waves in four ways, viz., sequence, amplitude, direction, and duration. In the case of any serious structural change in the heart between the auricles and the ventricles, the orderly spread of the impulse is interfered with. If this interference is extreme the impulse does not pass at all and as a result the auricle and the ventricle beat like separate organs. In this case the rate of the ventricle is about twenty-eight per minute and the rate of the auricle seventy-five or more. In the records which we shall have to show of this condition the P waves (auricular activity) appear in perfect order and the R and T waves (ventricular activity) are shown in normal seqence, but without any time relation to the auricle.

Sometimes the auricle is paralyzed and does not produce any one large contraction wave. Ordinarily this paralysis is of a trembling type and generates a great many very small impulses and causes quite a number of small currents. This again is excellently shown in the electrocardiogram. In other instances where the auricle does not contract regularly, it seems to fall under the influence of the nerves of respiration. This incident is very frequent in children. The knowledge of this fact has made it possible to give liberty to many children supposed to have inflammation of the heart when, in reality, they have nothing of the sort.

Before closing this chapter in which we have explained at some length the groundwork of electrocardiography, in a manner which we hope will induce the physician to take sufficient interest to delve into its interesting questions for himself, let us try to answer a very practical question, namely, What is its actual clinical value to the average physician, and to what extent can he rely on it?

The electrocardiogram has greatly advanced the discovery and certainty of diagnosis of cardiac conditions. In such conditions as cardiac enlargement it is possible to discover which chamber of the heart is the predominant one. Confirmatory diagnosis can be obtained in such conditions as mitral stenosis, aortic valvular disease and congenital heart troubles. The progress of the patient when taking certain cardiac remedies

can be appraised by the electrocardiogram, and the physiologic tolerance of such drugs estimated. The condition of the heart when affected by acute infectious illness can be studied, as also its functional activity and alterations in structure of the myocardium, by records taken at intervals over a long period of time. Many atypical conditions and arrhythmias can be strikingly illustrated by the electrocardiogram as in no other way.

Many obscure cardiac conditions need the enlightenment which is shed by the electrocardiogram before they can be duly recognized and the proper treatment instituted. Carefully repeated records, taken from time to time and under different conditions of stress or physical variation, are necessary for the well grounded study of the heart in all its aspects.

At times the auricle takes on a very rapid and regular action which is so quick that the ventricle is not able to respond, and therefore answers to only every other contraction or every third contraction of the auricle. There are also the types of hearts that beat rapidly at inconvenient times and cause people to say that they are suffering from palpitation. Sometimes this is the fault of the auricle and then again it may be that of the ventricle. When the electric picture of the heart is carefully studied all these things become perfectly clear.

We have seen that altered *direction* of the waves is one of the abnormalities, which is seen in the charts of disordered action. Some of these alterations of direction which may be noted are: inversion of all waves in Lead I, signifying dextrocardia (very rare); (2) right ventricular premature beat, as indicated by a premature R wave, positive and usually notched, seen in Lead II; (3) left ventricular premature beat, negative in Lead II; (4) premature auricular contractions is shown by a premature P wave, and often one that has an altered shape.

CHAPTER III

THE TIME ELEMENT IN THE ELECTROCARDIOGRAM

We saw in Chapter II, pp. 17 and 18, that the electrocardiogram possessed three elements, of which the time record was one. We will go a little more fully into the timing of events, as it is one of the most important factors in the picture of the heart beat. In fact it is just as useful for us to know that the cardiac events are being correctly timed, as it is for a clock upon which we are depending to strike twelve, at the exact time that the hands are pointing to that hour. We can imagine that if the clock strikes at any odd time, independently of the hands, we could not stake much on its reliability as a timekeeper.

In examining the pictures of the heart beat, as we have said, there may a wide range of variation within the limits of the normal; thus the shape of the picture may be altered by outside circumstances in such a way that the auricular wave (P wave) may be small or large. This is also true of the ventricular wave itself, as well as the wave which represents the work of the ventricle. Seeing that the waves may be frequently altered in design, it is fortunate that the time of their appearance can be accurately recorded on the electrocardiogram, and this is done by the time marker which makes a little dot or line every fifth of a second or so on the picture. Without this we should be like people looking out of the window to see what time of day it was, by the height of the sun. With an accurate time piece the sun can peep in and out of the clouds as it pleases, we do not have to depend on it. Therefore, we can forget the shape of the drawing entirely and identify the different currents by their type and the time of their occurrence. That is we can measure the time that elapses between the work of the auricle and that of the ventricle, and when the ventricles lag behind the auricle, we can tell which ventricle is falling behind and to what extent.

In this respect the electrocardiogram is far superior to pulse tracings because the wave from the auricle is recorded at the neck only a few inches from the heart, and the wave from the

ventricle is taken at the wrist, about three feet from the heart. The measurement of the time between these two events on a polygraph is not perfectly reliable, as these waves travel along the blood current at a comparatively slow rate. Since, however, an electric current can travel around the world in an inconceivably short time there is no appreciable difference in the length of time which elapses in the transmission of the current from the auricle and the ventricle.

In a healthy person the heart beat starts in the auricle and from thence travels down the connection which unites the auricle to the ventricle. This is a very definite structure which is named the auriclo-ventricular bundle. It consists of a main stem which branches off toward the two ventricles, and it is along these branches that the impulse of the heart beat passes and carries its influence to the ventricles. This viaduct between auricles and ventricles is rarely put out of commission, that is we seldom find it the seat of disease; but sometimes a hardening of its structures occurs and the heart beat, as it travels down, finds a difficulty in overcoming the obstruction to its passage. The electrocardiogram, which faithfully records any disturbance in the work of the heart, shows immediately that the electricity of the ventricle is much later than it should be after that from the auricle. This means that the impulse has had great difficulty in coming through at all, and this serious interference is spoken of as "delayed transmission."

"Delayed transmission" is a fact of great significance in the electrocardiographic examination. It is the first step of a condition which marks complete severing of connection in the sequence between the auricle and the ventricle. When the auricles and ventricles act independently of each other, it is because the impulse between them is blocked. This condition is known as heart block and it will be dealt with fully in a later chapter.

An outside factor which can produce delayed transmission is the administration of large doses of digitalis.

At this point we might recall a few points in the anatomy and physiology of the heart. As to anatomy, the most important structure that those who graduated in medicine ten or fifteen years ago might be not familiar with is the so-called bundle of His. Many physicians get the impression that because

this structure was so late in being recognized and its discovery was so much a matter of comment, that it is a very difficult structure to see. This is not true, particularly in the ox heart and also in the human heart, if we realize that we have been looking at it all our lives without knowing it. We mention the ox heart because you can order an ox heart from your butcher and dissect it any morning you feel like it. Indeed, for men in practice who seldom have occasion to see the heart in action, it is a pleasure to re-study an animal's heart once in a while. If your butcher can do so, have him get it with a good part of the aorta attached. Sometimes it is easier to get a sheep's heart with the adjacent vessels, than to obtain a bullock's heart, but the bullock's heart being larger is better. At the same time that you note the bundle of His, you can also study carefully the beautiful workings of the valves and chambers. What is worth emphasizing is that the bundle of His is not a microscopic structure and there is nothing mysterious about it any more.

In general it may be said that there are two ways to pursue these studies. We can, on the one hand, approach the subject from the purely practical point of view, adopting the best working theories and avoiding special attention to matters of controversy, and immediately apply what we know in the care of our patients. Or, on the other hand, we can attempt to follow out electrocardiology to the last analysis which involves an intensive study of electricity, physiology, and pathology. For most men this intensive study is absolutely inpractical, but there is no reason why one should not learn to use the facts of electrocardiology, just as one often speaks a foreign language without special knowledge of grammar. It would be a foolish man who starved in a foreign country while he was waiting to perfect his knowledge of grammar, instead of using the few broken sentences that he could utter for the practical purpose of obtaining a meal. The best method for the actual practitioner of medicine is to study intensively such examples of irregular hearts as come under his notice, making this a foundation for the general mastery of the subject. Any attempting to study the subject beginning with the complete study of physiology, is doomed to failure with the average man, unless he be a very young man under the discipline of academic control.

CHAPTER IV

SINUS ARRHYTHMIA

The form of sinus arrhythmia met with in childhood is very naturally the type of irregularity to first claim our attention. Owing to the relative instability of the nervous system in the child, as compared with the adult, the child's heart is never absolutely regular. The irregularity noted it that of a varia-

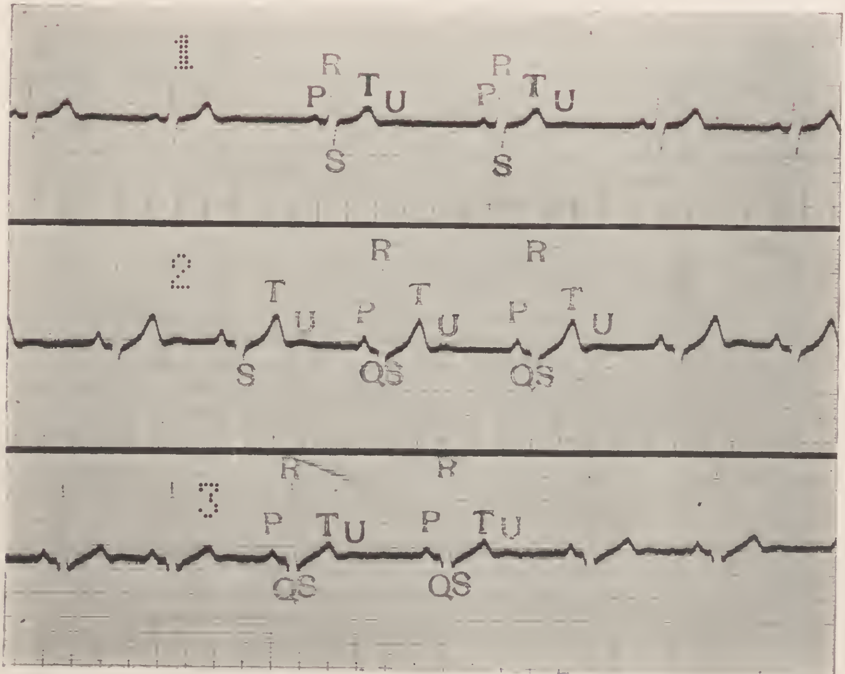

FIG. 4.—Electrocardiogram of a boy 14 years of age, showing sinus arrhythmia. There is no difference in the waves from one heart beat to another, but there is a continual variation in the spaces between the different beats. In all three leads, all of the waves are indicated by their letters for two heart cycles.

tion in the spacing of the beats. Each beat is as it should be in itself, but there is a gradual changing in the space between the beats so that they tend to become nearer together, and then further apart.

It is well at the outset to avoid laying over importance on this phenomenon. The tendency in childhood to "run a tem-

perature" for comparatively slight cause is well known; a thermic chart which would in an adult give rise to uneasiness, is often in a child of little significance, and accompanies a digestive upset, over fatigue, or excitement. This is particularly true in nervous "fidgety" children. The same thing is true of the heart's action. The undeveloped state of the nervous system in the child makes it prone to react to some excitement, out of the normal course of things, with a pulse rate which would represent an unusual velocity in the adult. This is particularly true in regard to the doctor's visit. The average child is apt to feel that his life is in danger if he does not regard

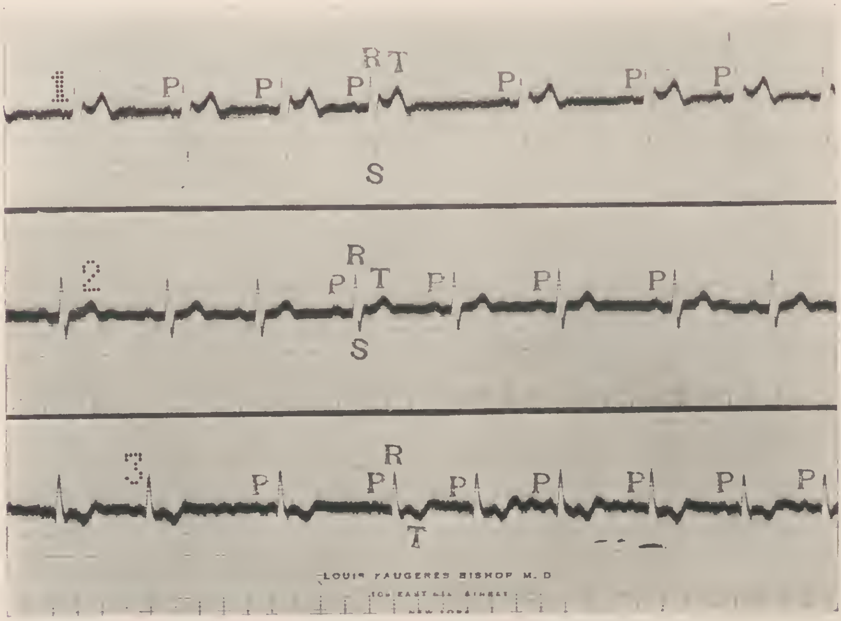

FIG. 5.—Electrocardiogram with a marked degree of sinus arrhythmia. Some of the long pauses are almost twice the length of the shorter ones. This record also shows right ventricular preponderance.

the physician's proceedings with suspicion, and the element of fear or shrinking in nervous children gives rise to a quickened pulse that the doctor, on his first visit cannot attribute entirely to disease. Quieter conditions, or a subsequent visit, will often show that the pulse has subsided to normal.

Sinus arrhythmia, although quite essential in all children, varies greatly in the different physical types. In some, the irregularity is barely noticeable, whereas in others it is so

marked that it makes us wonder for a time whether a child with such a rhythm, can, after all, be entirely normal. Before the days of accurate heart measurement a child with a marked sinus arrhythmia was often supposed to have a grave disturbance of the heart and was put to bed for long periods of time, kept from school, and made to rest. As a result the child, instead of developing into a sturdy youth through play and exercise, became a pathetic little invalid.

In order to be able to teach the parents of these children that they may safely disregard this irregularity, without risking

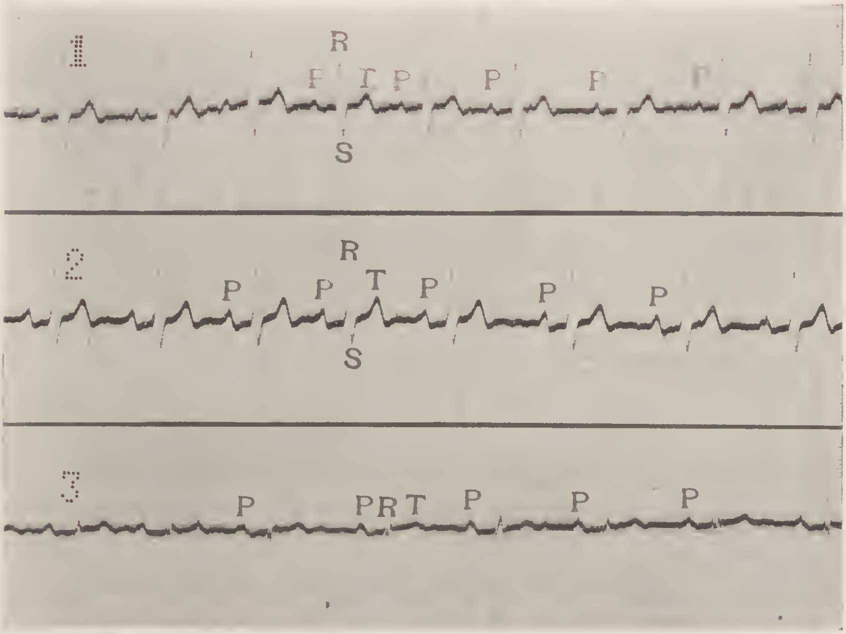

FIG. 6.—Electrocardiogram demonstrating a slight degree of sinus arrhythmia. The change is best observed in Lead I. There is a slightly prolonged P-R interval, which indicates a tendency to heart block. Both the sinus irregularity and the heart block are due to digitalis.

the health of their beloved charges, we must thoroughly understand and be able to point out the manifestations of such changes. Sinus arrhythmia is nothing more or less than a periodic quickening and slowing of the heart rate. Normally in the child the heart quickens during inspiration and slows during expiration. As youth approaches, this variation is apt to be lost and by adult life it has altogether disappeared. In a young subject this change in heart rate may be produced by

deep inspiration and expiration. A few persons show sinus arrhythmia during their whole lifetime, although in the latter case the abnormality may be independent of respiration.

Much has been studied and written in regard to the loss of balance between vagus and sympathetic control, and a certain school of thinkers has gone so far as to attribute a whole class of diseases to "vagotonics" and to look for another set of symptoms in "sympathicotonics"—but the subject is very far from being unravelled, and is further complicated by the

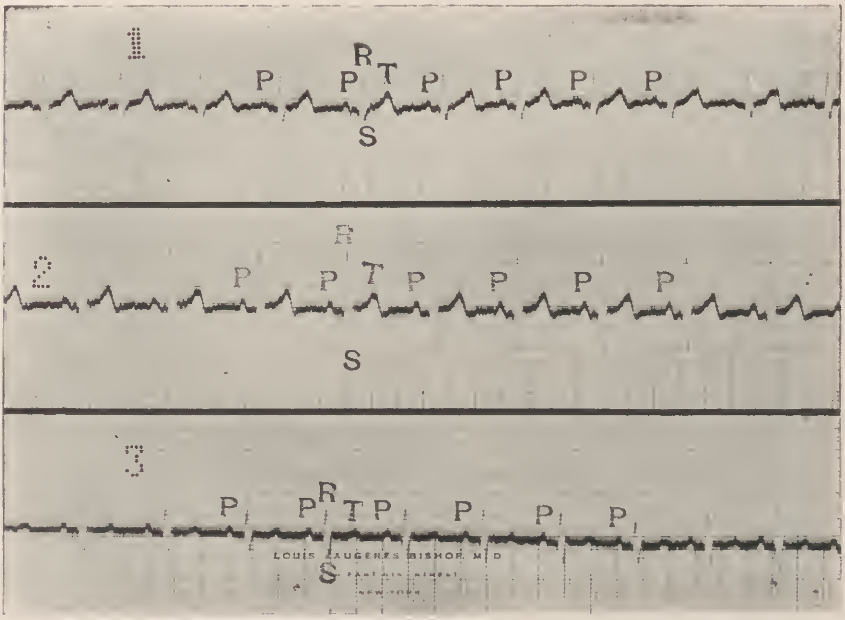

FIG. 7.—Electrocardiogram, showing slight sinus arrhythmia, which is only observed by a careful measurement of the spaces between the beats.

mutual relation of these plexuses with the endocrine system; it is an established fact, however, that the vagus nerve takes a much higher degree of control in some persons than in others, and that the functions under its domination are correspondingly modified. A heightened vagus control, for instance, tends to keep the pulse rate down in persons who show vagus predominance. "Vagotonicity"—to borrow a phrase from some advanced workers—produces a slow pulse after slight exertion, and during the convalescence after an illness. While other persons, in whom another portion of the nervous system coun-

terbalances, or tends to get the upper hand, show a naturally accelerated pulse.

In connection with the latter manifestation, it is quite conceivable that in youthful subjects of a highly strung or neurotic type, nervous imbalance may produce an excitation of the pulse without any definite organic disease. The heart may be looked upon as "irritable" and likely to establish an abnormal rate, which will persist for a long period of time, even under ordinary conditions. The rate will be decidedly increased under the stimulus of excitement, fatigue, etc.

The important point to remember in regard to sinus arrhythmia is that modern cardiology has taught us to appraise it at its true value, and that we may safely discard it as a factor of clinical significance. Formerly it was supposed that this was a form of heart disease, necessitating a life of semi-invalidism for the unfortunate child in whom it was noted. The electrocardiogram has proved a real blessing, in that it shows this abnormality to be so common as to be practically normal, and thus releases the little person who manifests it from the result of fears of the over anxious parents, and permits him to romp, play, and study his way along the normal path of development.

CHAPTER V

PARTIAL HEART BLOCK

INSTANCES IN WHICH THE VENTRICLE ACTS ABNORMALLY AFTER THE AURICLE

It is advisable to consider first for a moment the fact that impulses are carried from one part of the heart to another and it will be found that many heart irregularities are due to some defect in this conduction system. The system can be thought of as being composed of fibers which carry impulses. These impulses are first originated at what has been named the "pace-maker," which is situated high up in the auricle and consists of a tiny bundle of specialized fibers. From the pace-maker these impulses are transmitted over a system of paths which run through the walls of the auricle and then they all join again to form a cable which traverses the partition between the auricle and the ventricle. This cable is known as the "bundle of His." As it emerges into the ventricle the strands again separate into two bundle branches and then into countless branches which spread all over the walls of the ventricles.

Each impulse from the pace-maker acts on the auricle, which in turn contracts, and then the impulse passes through the cable into the ventricle, which also responds by contraction. If the heart is normal this occurs with every heart beat and carries on with monotonous regularity throughout life.

Of course, these impulses travel very quickly and the ventricle will not act until it receives its impulse, which occurs at about one-fifth of a second after leaving the auricle. After the ventricle contracts, it rests until the next impulse is received.

The cable occasionally becomes injured or gets partly out of order in some other way. This occurrence causes the impulses coming from the auricle to have difficulty in passing through the injured cable, and it therefore takes a longer time than normally. When the current finally reaches the ventricle, the latter contracts. As there is nothing the matter with the wires in the

auricle the next impulse reaches the cable in normal time, but this again has difficulty in transmitting it. These impulses as a result often begin to pile up within the cable and some of them may be lost and the ventricle, therefore, beats less often than the auricle. This condition is called "heart block" or partial heart block, because the bundle is not entirely severed but still works imperfectly.

What, then, will be the autograph of such a heart when seen in the electrocardiogram? The P wave, as has been seen, re-

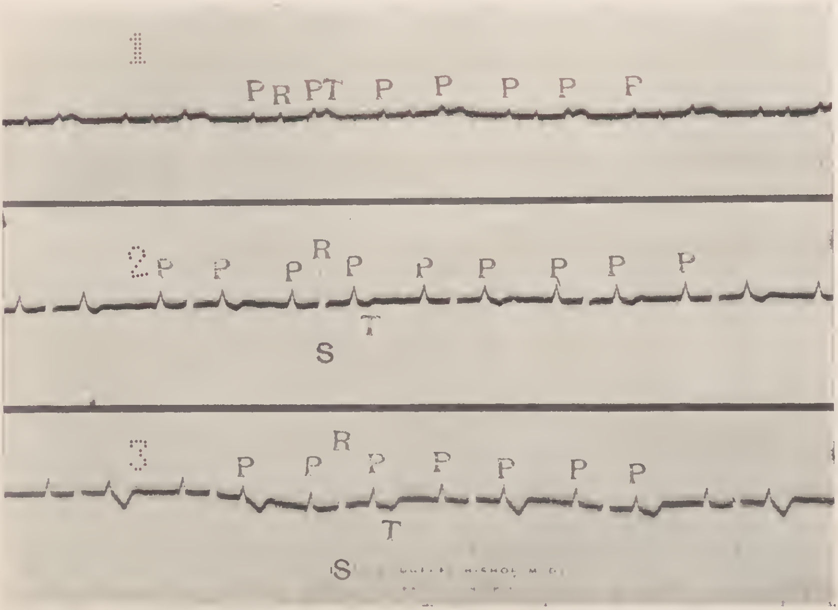

FIG. 8.—Electrocardiogram illustrating heart block. Every other auricular wave is followed by a ventricular contraction. The stimulus from the intermediate auricular contraction is blocked. When the stimulus passes from the auricles to the ventricles the conduction time is 0.26 second, which is abnormally long.

presents the contraction of the auricle, and the R wave that of the ventricle. The interval between the two is called the P-R interval, and normally takes about one-fifth of a second. This time is indicated by the vertical lines on the film. In heart block the P-R interval is naturally lengthened, because this is a record of the time it takes the impulses to pass through the cable which is damaged in heart block.

Sometimes this may be the only evidence of heart block that can be found. Or one of the waves occasionally will fail to get

through if the condition is a little more severe and there is a loss of the P waves at the ventricular end of the cable. In more advanced conditions many waves fail to get through and so the auricle is found to be beating at a faster rate than the ventricle. These rates are often spoken of as "three-to-two block," the three representing the auricular beats and the two the ventricular beats; "four-to-two block," and so forth.

Since the P wave always means auricular contraction, more

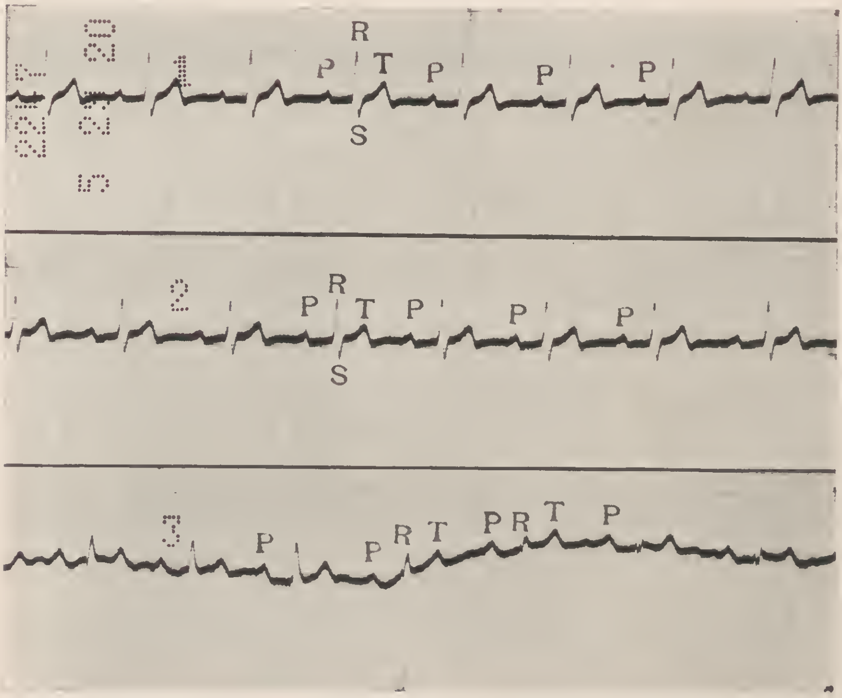

FIG. 9.—Electrocardiogram illustrating the earliest manifestation of heart block. In this record the interval from the beginning of the P-wave to the beginning of the ventricular wave measures 0.28 second, which is distinctly too long. This shows diminished function of the function of the A. V. bundle, which is the lowest grade of heart block.

P waves than R waves would be expected. This fact is what actually occurs.

Partial heart block may occur during all ages and from various causes, among the most important of which are: rheumatic fever, syphilis, influenza, typhoid fever, occasionally diphtheria and other acute febrile diseases. The taking of too much digitalis is another very important cause of heart block.

When heart block occurs it is a solemn warning to stop using the drug immediately.

The outcome of heart block depends, of course, upon the amount and character of the damage done to the cable. If there is a progressive lesion, such as a tumor, the condition will go on to a complete severence. In syphilis, the condition may be checked by anti-syphilitic treatment, although the strands already broken can never be replaced. After the acute fevers, excepting rheumatism, the heart usually returns to health. It

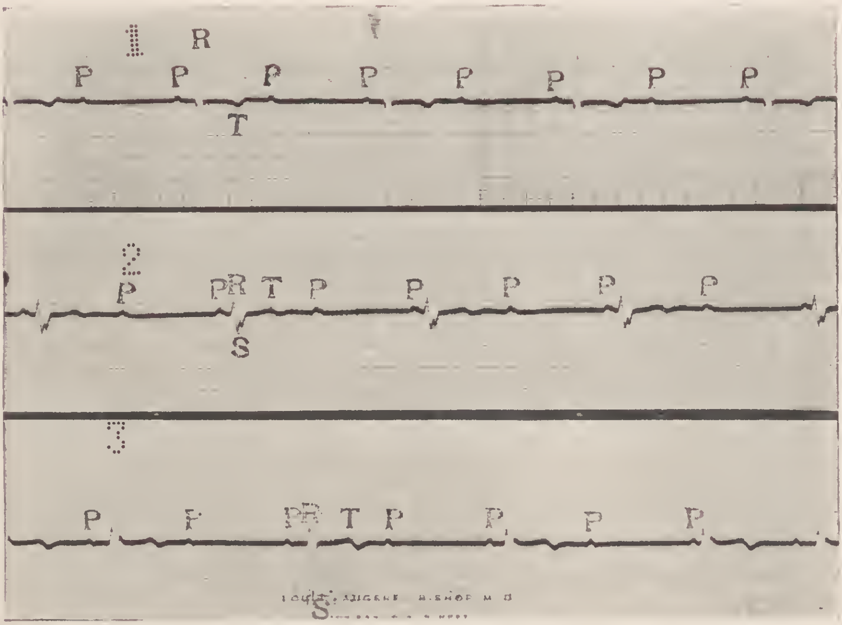

FIG. 10.—Electrocardiogram illustrating almost complete heart block. The auricular waves occur regularly 75 times a minute; the ventricular waves usually occur regularly 38 times a minute, and without any relation to the auricular contractions. Some times, as seen in Lead III, the auricular contraction is followed by a ventricular contraction, with a P-R interval of 0.20 second. This shows that the Bundle of His can still function and therefore the block is not complete.

is of great importance to remember that heart block resulting from too much digitalis may be relieved almost immediately by atropine.

Before exact methods of heart records came into practical use partial heart block was unrecognized and thus went untreated until the grave condition of complete heart block became established. How could any one tell that the auricle was

beating faster than the ventricle excepting when the auricular pulsations could be occasionally counted in the neck? And, still earlier, where only the P-R interval was lengthened, how could one perceive that fact?

So, this is just another instance where the electrocardiogram makes everything very simple, for it shows that some P waves are found to be occurring regularly without R waves following, and the P-R interval is discovered to be more than the legitimate one-fifth of a second in length. These signs all spell HEART BLOCK in capital letters and the physician who knows how to read this language can make use of modern methods, and is able to put into practice methods that would fail with a more limited knowledge.

CHAPTER VI

COMPLETE HEART BLOCK

INSTANCES IN WHICH THE AURICLE AND VENTRICLE ACT INDEPENDENTLY OF EACH OTHER

The preceding chapter has described in detail what happens when that bundle of fibers which carries impulses responsible for ventricular beats following those of the auricle is damaged.

If this bundle of fibers is completely severed a very remarkable thing occurs. It would be expected that if the ventricle was cut off from its dynamo it would not run, just as no explosion would take place in a cylinder of a gas engine if there was no spark. If this were true, life could last but a moment after the connection was broken, for that portion of the heart which supplies blood to the body would fail to beat. Nature has provided for this condition in a curious way. If the "bundle of His" is completely blocked, the ventricle immediately becomes its own dynamo and begins to beat absolutely independently of the auricle.

In such a condition the ventricle will contract at a slow rate and directed by impulses coming from a new point of stimulus production in the ventricle itself. Or impulses may be only partially lost in the bundle and provoke the so-called "two-to-one block," or three-to-one block."

Although one would expect that the electrocardiogram of this condition would be very similar to that of partial heart block, this is not always the case and complete heart block signs its name in unmistakable letters. This is explained by the fact that, whereas in partial heart block there are many P-R-T complexes, even though the P-R interval is lengthened, in complete heart block the P portion and the R-T portion have nothing to do with each other. This is, of course, due to the fact that the connection between the auricle and the ventricle is completely severed and the P current ends at the break of the wire. The ventricular contraction which is induced by its

own independent current is no longer influenced by the auricle but takes place at another time.

The autograph would, therefore, have P waves occurring at regular intervals and since these normally would represent the normal pulse rate they probably would lie somewhere between 70 and 90 per minute. The R-T waves are seen in fewer numbers than the P waves, as the independent rate of the ventricle is usually a slow one. Occasionally they reach an extremely slow rate which at times is as low as twenty per

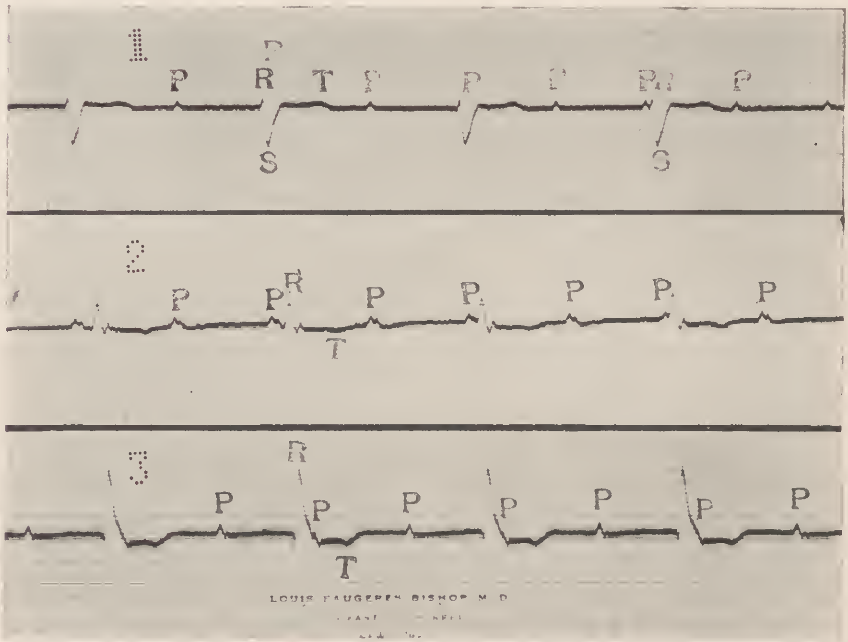

FIG. 11.—Electrocardiogram illustrating complete heart block. The auricular waves occur regularly at a rate of 60 times a minute. The ventricular waves are slow and regular at 40 a minute. These ventricular waves are abnormal. (See Chapter on Bundle Branch Block.)

minute. It may sometimes happen that a P wave will appear just before an R wave, thus giving the appearance of a normal P-R-T complex, but such an occurrence is only occasional and accidental. In the same way, if the waves happen to coincide the P wave may be entirely lost if consolidated in the R or T wave.

Complete heart block is a serious condition, for it indicates that extensive damage has been done the heart. There is little

hope for its cure excepting when due to syphilis or overdoses of digitalis. Heart block should always be suspected when the pulse rate is below fifty and the patient should be immediately sent to the nearest available electrocardiograph for study.

Adams-Stokes disease, in which there are fainting attacks, is evidence of complete heart block. These attacks may be due to insufficient blood supply to the brain from the heart which is beating so slowly it cannot supply the vital necessities of the brain.

CHAPTER VII

PREMATURE CONTRACTIONS

INSTANCES IN WHICH THE AURICLE OR THE VENTRICLE ACTS OUT OF TIME

Thus far, the disturbances of the heart beat which have been described have given normal P, R, and T waves, although the

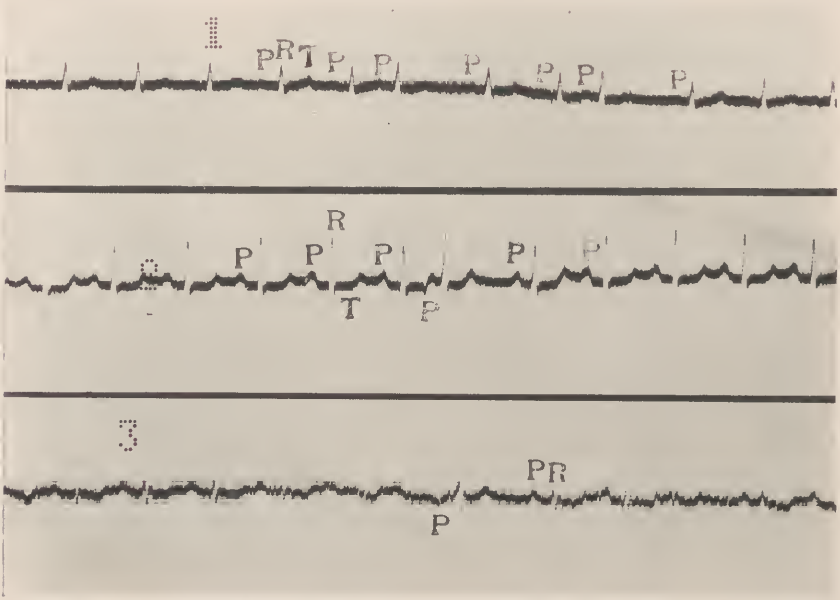

Fig. 12.—Record of a patient who had auricular premature beats. In Lead I and Lead II the premature beats of the ventricle are seen preceeded by a different shaped P-wave due to the premature auricular contraction.

interval between these waves may have been lengthened or shortened. In other words, the heart muscle has been to all appearances, normal, and the disturbances rested with the conduction system. The parts of the telegraph system which send and receive messages may be in excellent working order and capable of transmitting correct messages but if the wires are damaged they cannot function properly.

Let us now see what happens when the conduction system

remains intact but the heart muscle itself does not function correctly. In this connection the auricle should be considered first. Thus far, the auricle has contracted in a normal manner in response to stimuli received from the normal pace-maker. This records itself by a deflection of the string in the electrocardiogram forming the natural P wave. As occasionally happens, an impulse may arise elsewhere in the auricle than at the pace-maker which really may be anywhere. Some point may become over-irritable and momentarily supersede the in-

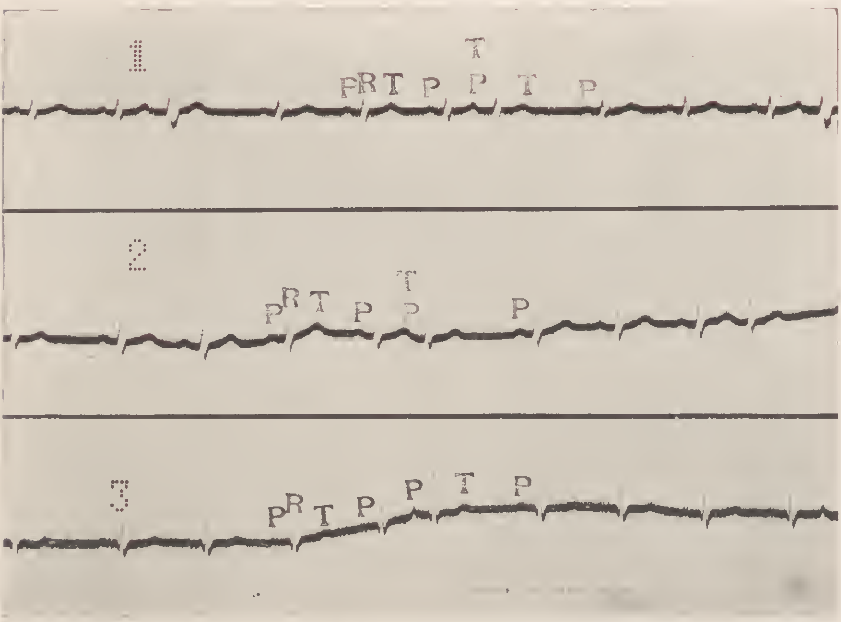

FIG. 13.—Record of a patient who had auricular premature beats. In Lead II the premature P-waves cannot be plainly seen, but in Lead I and III, they can be made out, falling on the top of the T-wave preceeding.

fluence of the pace-maker and thus set the pace from there. When this happens a distorted P wave is found instead of a normal one. Such an impulse travels down as well as up through the auricle to the connecting bundle and finally sets off the ventricle. The ventricle, being undamaged, cares little where the impulse came from and does its duty by contracting.

It is as if some one tapped in on a telegraph wire and sent a message. The recording instrument at the other end responds with its usual clicks and does not distinguish whence the mes-

sage came. The R-T or ventricular complex will thus be a normal one.

We, therefore, distinguish between what are known as "premature contractions" of the auricle and normal ones. They are called "premature" because they come between two normal beats and therefore appear before the second normal beat. In order to illustrate this point further, consider that the heart is beating at a normal rate of about eighty per minute. Each P-R-T complex will be equally spaced from every other and

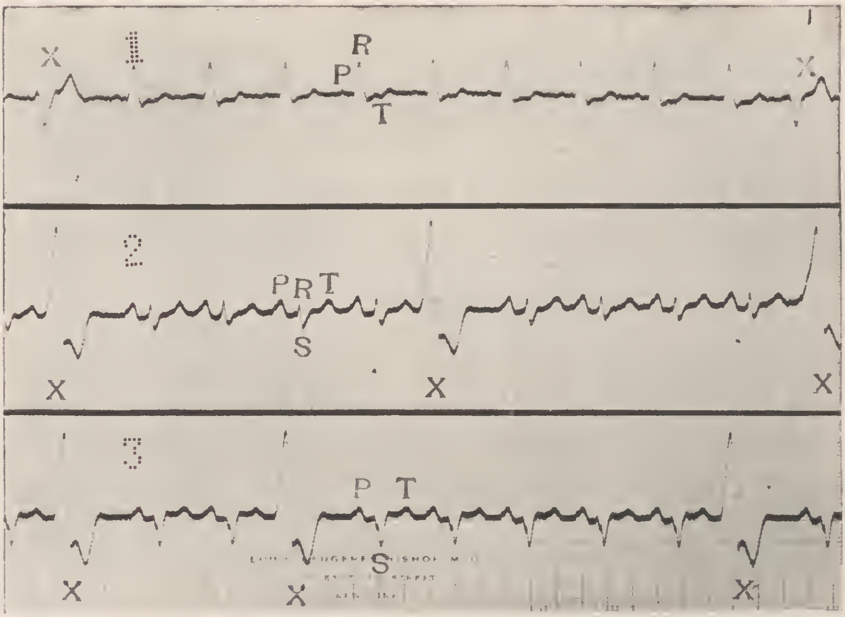

FIG. 14.—Ventricular premature beats X coming from the right ventricle. Notice how these waves differ from the usual waves of the electrocardiogram.

all will have a perfectly similar shape. A queer looking complex is suddenly thrown in and on examination it is found there is nothing wrong with the R-T part of the complex but the P wave is either upside down or taller or perhaps wider than the other P waves. This finding spells "auricular contractions," otherwise known as "auricular extrasystoles." (Fig. 13)

If the irritation which causes these premature contractions is of longer duration there may be two or three more extrasystoles following each other in sequence and then returning to normal rhythm. It must be remembered that while these

contractions are going forward, normal impulses are coming from the pace-maker. These, being absorbed in the abnormal complexes, however, become lost.

The ventricle may beat out of time in the same manner as the auricle. In this case there is nothing the matter with the auricle. There has been, however, a point of irritation set up somewhere in the ventricular wall which has started independent contractions, and since these have not occurred through

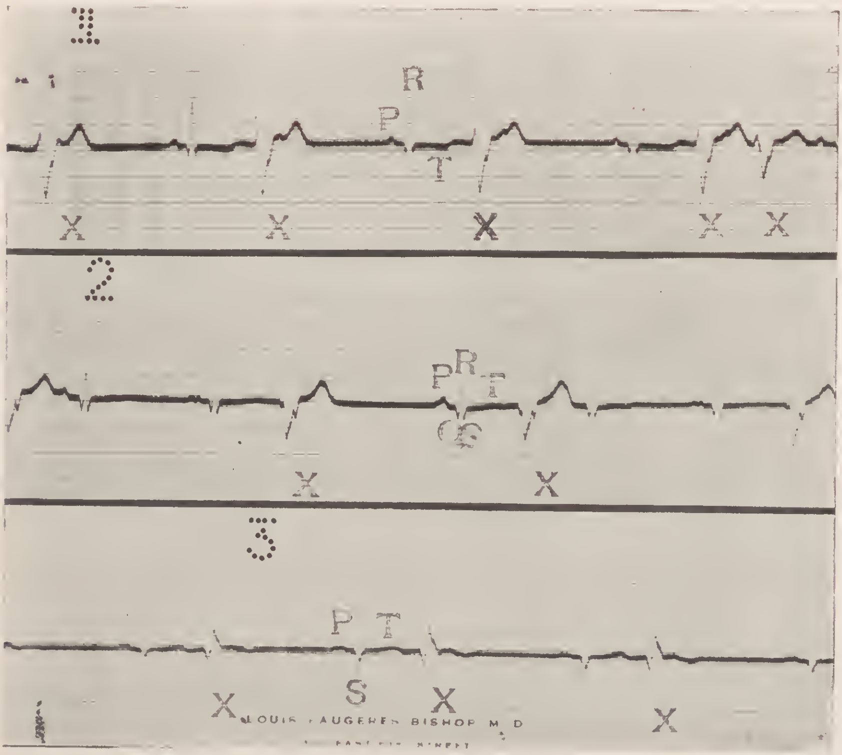

FIG. 15.—Record of a patient who had bigeminal rhythm X due to ventricular premature beats from the right ventricle. In Lead I, two ventricular premature beats occur together. This is sometimes a digitalis effect.

normal paths, their records will be abnormal. Such a record will consist of badly distorted R-T waves, the amount of distortion depending on how far the point of irritation lies from the normal pathway. These deformities may be extreme and may dip down below the line to a considerable extent or they may go high above the line. Sometimes they are both above and below the line in the electrocardiogram.

In ventricular extrasystoles one usually has to deal with a decided disturbance in rhythm due to what is known as the "compensatory pause." The meaning of this term is simply that when the ventricle is stimulated during contraction it will not respond to the stimulus so it waits for the next stimulus from the auricle.

Picture again a regular heart rate with normal evenly spaced and similarly shaped P-R-T complexes. A bizarre shaped wave is suddenly found to be thrown in. On measuring the width

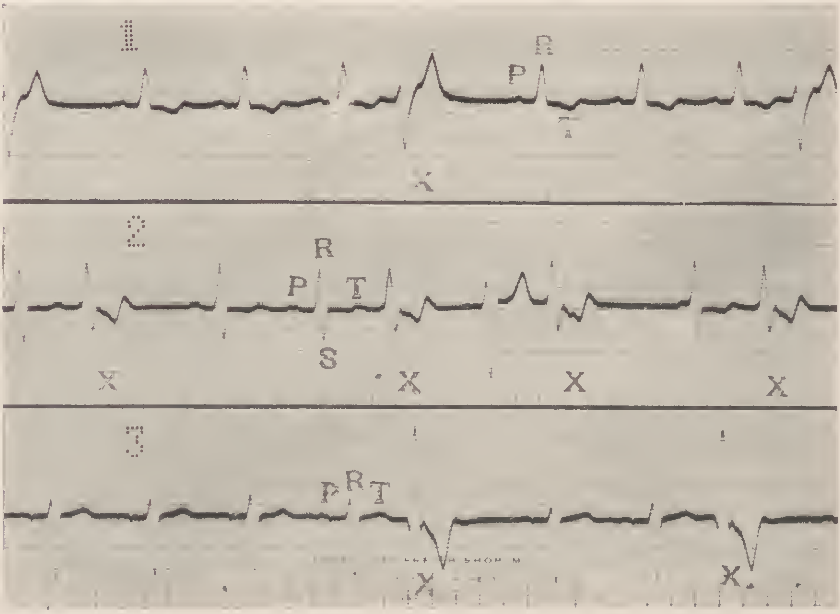

FIG. 16.—Another instance of premature ventricular beats (X). These have very large waves due to beats from the right ventricle.

of this wave it is discovered that it is equal to that of any normal preceding R-T complex, indicating that it comes from the ventricle. Meanwhile, normal P waves are occurring and when one of these falls on such an abnormal complex it finds that the ventricle has already contracted and is therefore unable to respond. There is then a pause where nothing happens until the next P wave occurs. This is the "compensatory pause" mentioned above.

There may be several ventricular contractions following each other just as there may be many auricular contractions in

auricular extrasystoles. There is a series of weird waves of various shapes here also, but whereas in the first instance they were followed by normal R-T complexes, in this case they consist of abnormal R-T complexes.

When ventricular extrasystoles occur in series they do so rhythmically, that is, there may be two of them followed by two more, then two more and so on. This is called "coupling" and gives rise to the well known term "pulsus bigeminus." If the extrasystoles occur in threes the condition is called "tripling" and is spoken of as "pulsus trigeminus" and so on. It is well

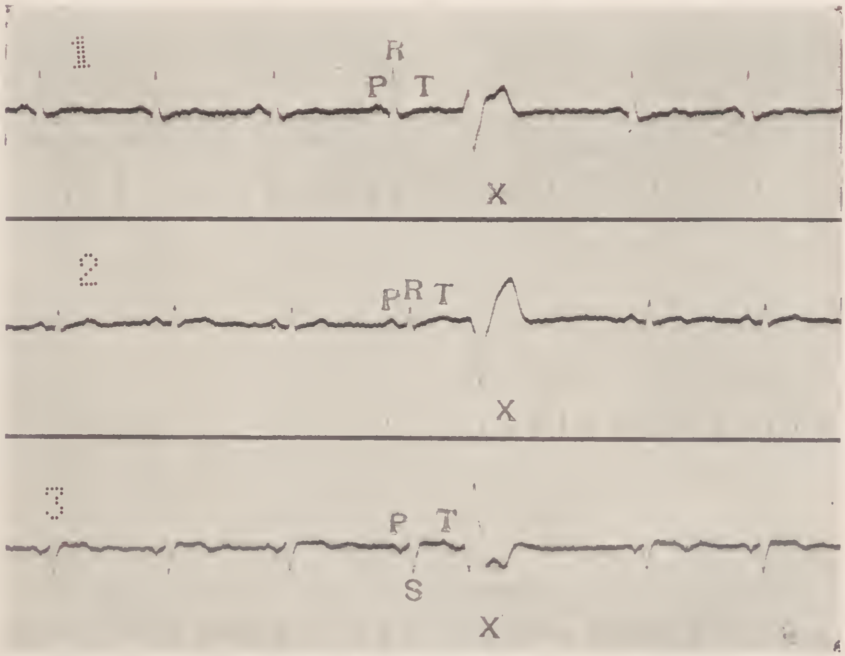

FIG. 17.—Record of a patient who had only occasional ventricular premature beats (*X*). Note how much these waves are in contrast to the waves of the ordinary beats.

to remember that such series are one of the first indications of over-doses of digitalis.

Of course, there may be many variations in extrasystoles. For example, there may be both auricular and ventricular extrasystoles, both starting from different foci, thus giving a series of variously shaped waves, or again there may even be extrasystoles beginning in the connecting bundle between the auricle and the ventricle. Although these may for the moment com-

plicate the picture, they can be readily understood by a brief study of the electrocardiograms.

With the exception of sinus arrhythmia, auricular and ventricular extrasystoles are the most frequent forms of irregularities of the heart beat. They are most often found in cases of long standing myocarditis, although they may occur at any age indicating a temporary derangement of the heart function. Their presence need be no cause for alarm as they, themselves, rarely embarrass, but they should be considered as indications of underlying cardiac damage.

CHAPTER VIII

SIMPLE PAROXYSMAL TACHYCARDIA

In order to appreciate the term, paroxysmal tachycardia, one must recall the fact that the vagus nerve acts as a brake on the heart. The heart will slow down markedly if this nerve is stimulated as, for instance, by pressing along the side of the neck. One releases the vagus nerve in this same manner by means of atropine which paralyses its endings. The heart will then tend to run away.

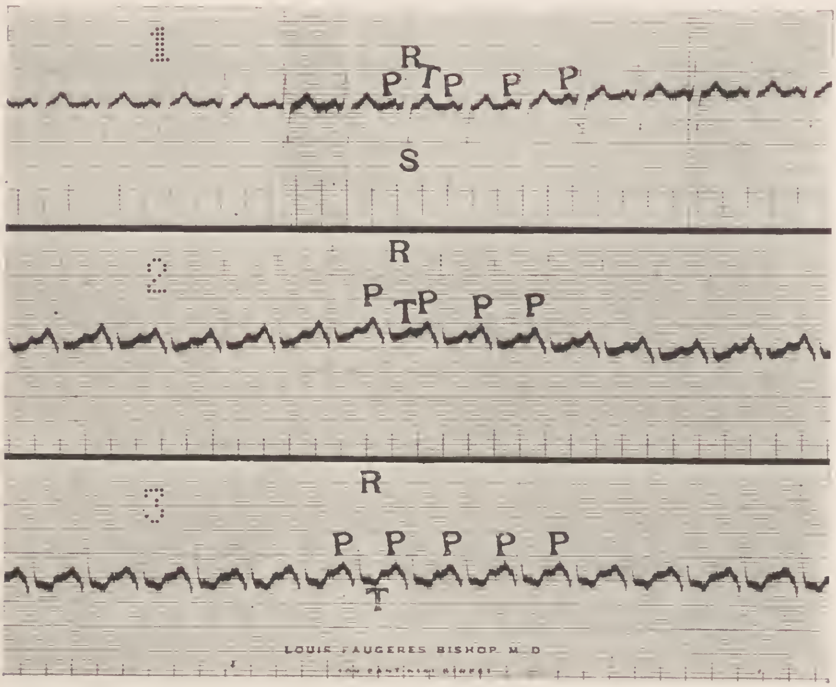

FIG. 18.—Record of simple paroxysmal tachycardia. The auricles beat at 140 a minute, and each auricular contraction is followed by a contraction of the ventricles so that the heart is regular. This record also indicates right ventricular preponderance.

Every one is familiar with the clinical condition known as paroxysmal tachycardia in which the rate of the heart is excessively fast. There are many evidences to show that this con-

dition is due to loss of control by the vagus nerve, thus allowing the heart to have its own way. One of these evidences is that pressure on the neck over the vagus nerve may frequently bring it under control.

It was the electrocardiogram which taught the mechanism of this disturbance. The statement has frequently been repeated that a normal heart beat gives a complex of three waves, P, R, and T, which although they may vary individually are nevertheless recognizable as normal curves. If it were assumed that the heart were beating regularly at a rate of about eighty per

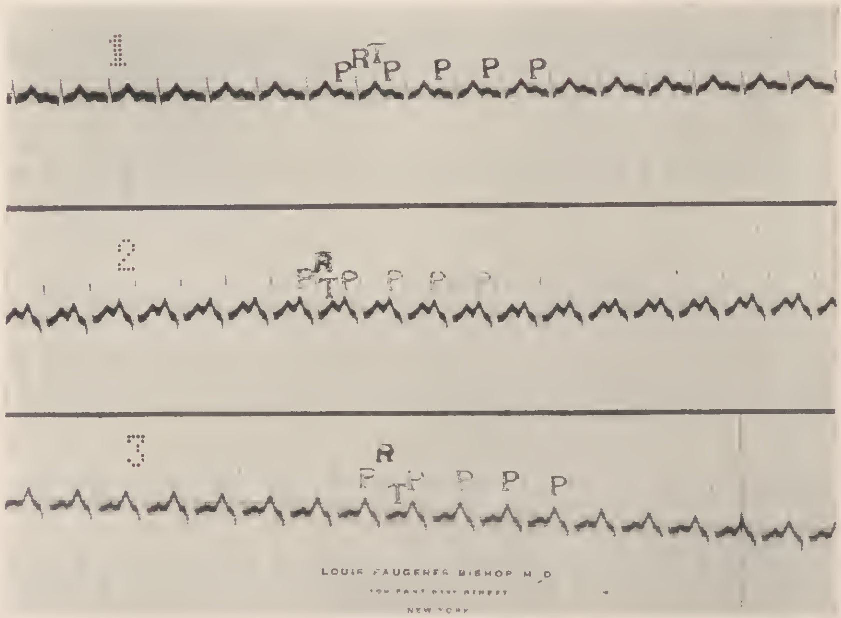

Fig. 19.—Record of simple paroxysmal tachycardia in which the auricles beat at 160 a minute, the ventricles follow regularly after the auricles.

minute, thus recording a normal autograph on the film, and if the rate were suddenly doubled or more than doubled it would indicate that a so-called paroxysm had set in. If the P-R-T complexes which now appear are examined, the R-T part of the complex is found to be identical with those recorded when the heart was beating normally. Since it is a known fact that the R-T wave spells the action of the ventricle it can be assumed that there is nothing wrong with this portion of the heart.

The P waves should next be examined and they will be found

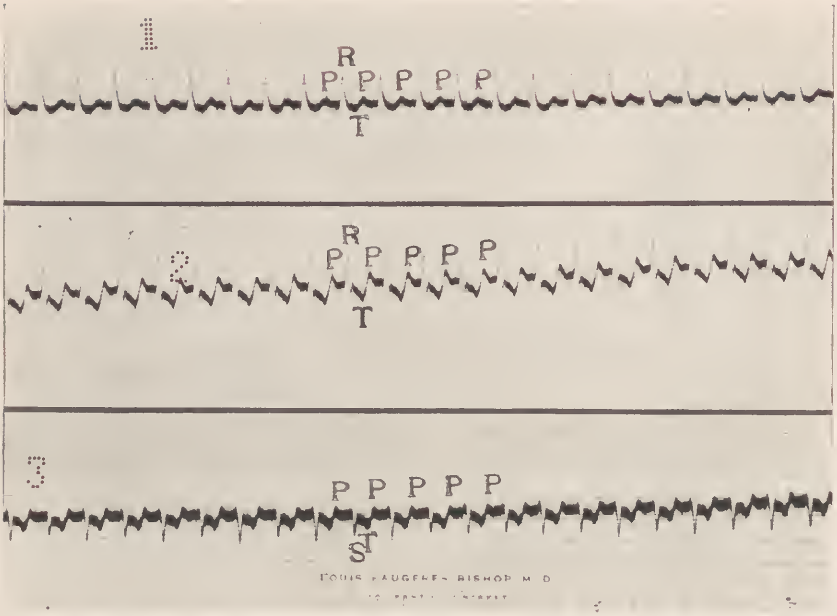

FIG. 20.—Record of a very rapid paroxysmal tachycardia. The auricular beat here is 200 a minute and the ventricles follow regularly after each auricular beat. The record also indicates left ventricle preponderance.

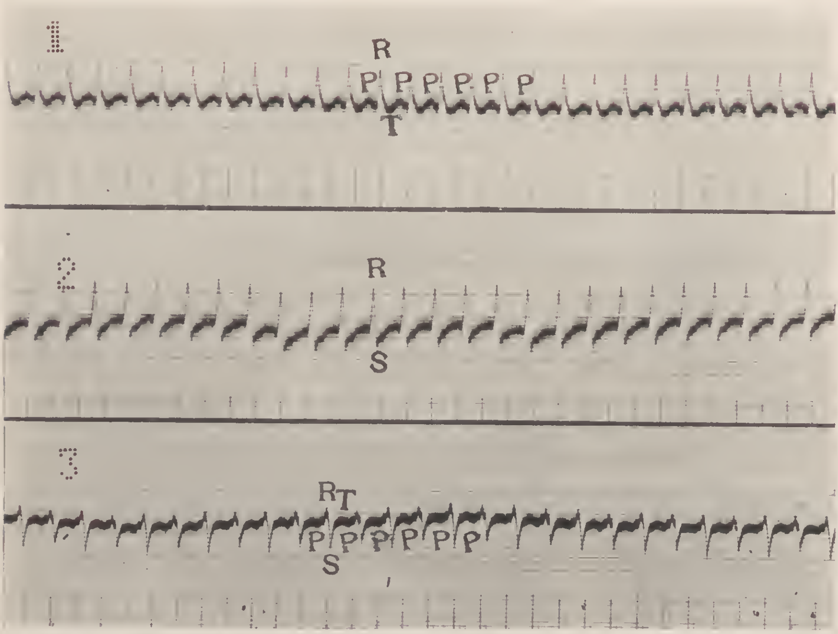

FIG. 21.—Record of an extremely rapid paroxysmal tachycardia, the auricular beat being 240 a minute. The ventricles follow regularly after each auricular beat.

to be entirely different from those which appeared before. They may be higher, of a different shape, inverted, or perhaps diphasic, that is, partly above and partly below the line but they certainly will be different.

The question is: What is the explanation for this condition? It simply means that there is a disturbance of the auricle and that instead of the impulses arising at the pace-maker, which always gives normal P waves, the auricle at some point has set up a new pace-maker which has over-ruled the normal one. The P wave from the new place has a different shape.

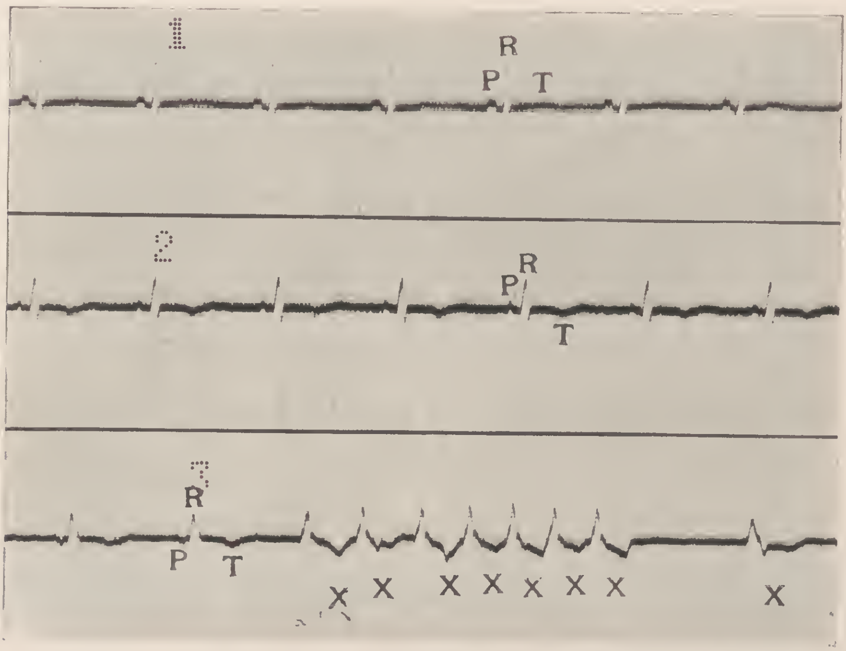

FIG. 22.—In this record Lead III illustrates a short paroxysm of ventricular premature beats (X) which constitutes a short paroxysm of ventricular tachycardia. The rate is about 175 while it lasts.

This picture of the activity of the auricle recalls at once that of auricular extrasystoles. To be sure, it is a matter of fine distinction as to whether or not paroxysmal tachycardia may be considered as a long chain of equally spaced auricular extrasystoles. This point is all the more suggestive when it is remembered that extrasystoles sometimes may occur in twos, threes, fours, fives, and so on, and in these instances the series may be extended into the thousands.

This amazing condition is usually found in young adults who may or may not have had previous heart trouble. Once heart trouble occurs in an individual, he is predisposed to other attacks. The attacks may last for a moment or may continue over a period of several days. If the latter, the heart may be considerably embarrassed. The presence of paroxysmal tachycardia should always lead one to look elsewhere for heart damage.

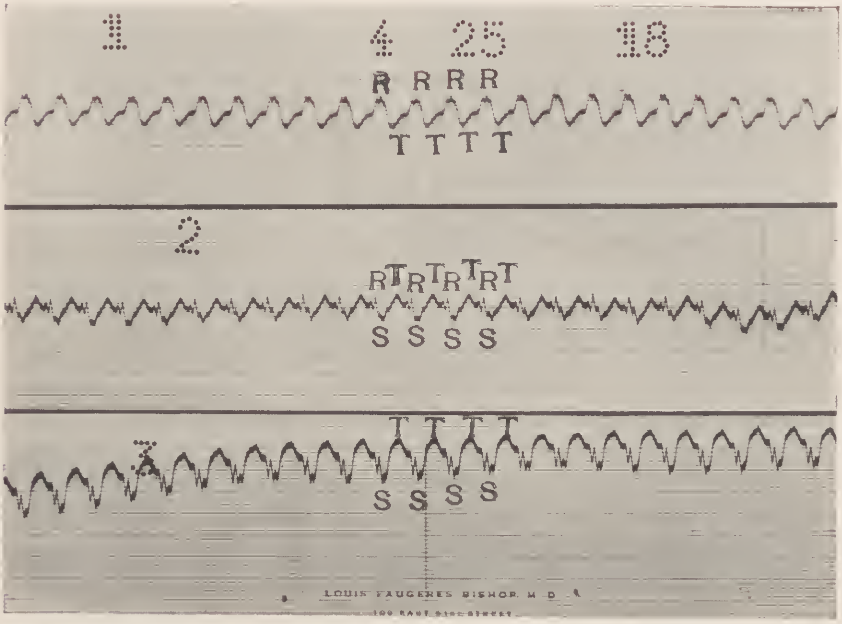

FIG. 23.—Record of a typical paroxysm of ventricular tachycardia. The ventricles beat 180 times a minute, quite regularly.

It is well to remember that although these attacks usually stop of their own accord quite as suddenly as they began, nevertheless pressure over the vagus nerve on either side of the neck, strong pressure upon the eyeball, or leaning far forward, may stop the attack immediately.

The electrocardiograph is the only instrument whereby one can distinguish between a normal over-acting heart, paroxysmal tachycardia, and auricular flutter which is fully described in the following chapter.

CHAPTER IX

AURICULAR FLUTTER

INSTANCES OF VERY RAPID ACTION OF THE AURICLE

All cases of extremely rapid heart action were classed as paroxysmal tachycardia until the accurate instruments which portray the action of the heart were perfected. It has been only recently that the electrocardiogram has revealed a condition which, although similar to paroxysmal tachycardia in its general picture, is quite different in its mechanism. This condition is called auricular flutter. It is important that it should be so recognized because it usually implies a greater degree of damage to the heart than that found in paroxysmal tachycardia.

The question is, why is this condition called auricular flutter? To begin with, as in paroxysmal tachycardia, the vagus nerve is apparently out of action and impulses are sent down through the heart at a tremendous rate of speed, sometimes 300 or more per minute. These impulses are transmitted as usual through the auricle and then through the connecting bundle to the ventricle which, in turn, responds by contraction. The ventricle, however, since it does most of the work of the heart by sending the blood into the circulation, requires more time for rest than the auricle. It cannot keep up with such an exceedingly fast pace. The result is that after the ventricle has contracted in response to one of these stimuli the next one, two, or three may find it either still contracting from the last stimulus or taking its needed rest, and therefore they have no affect on the ventricle.

The very rapid rate observed in paroxysmal tachycardia is not the only finding one discovers in looking at the electrocardiogram of this type. A great many P-R-T complexes will be found, but between each one of these there will be one or more isolated P waves. These are records of the contraction of the auricle to which the ventricle could not respond.

In the heart of a dog in which auricular flutter has been produced experimentally one will find the auricles to be beating so fast that they are in a continual state of flutter and hence the term, "auricular flutter."

Auricular flutter resembles heart block but in this instance there is no damage to the cable connecting the auricle and ventricle but in the ventricle itself, which refuses to work at any such exorbitant speed as the new pace-maker demands. Therefore, as in heart block, there is a two-to-one, three-to-one,

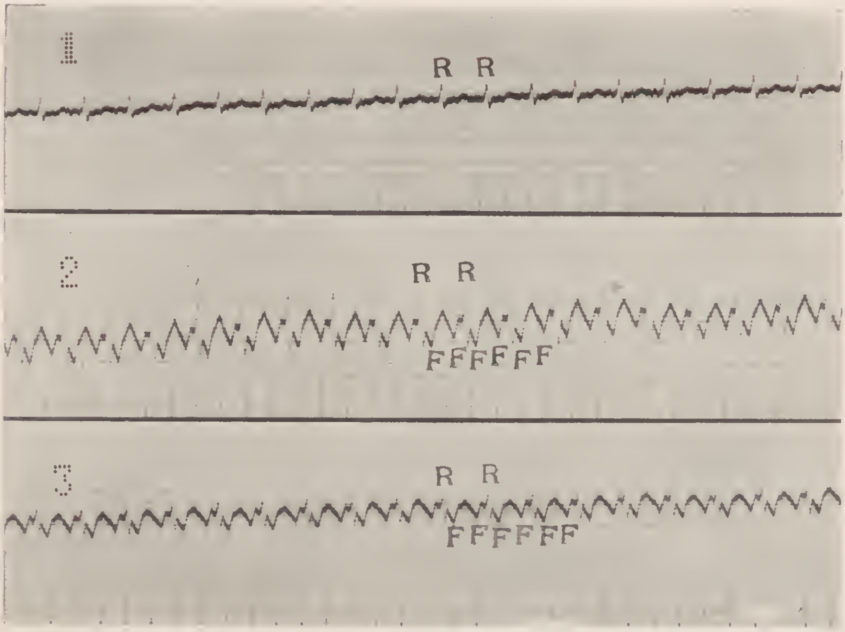

FIG. 24.—Record which illustrates auricular flutter. The auricles are beating 330 times a minute, quite regularly; the ventricles are beating at exactly half this rate. Flutter waves are marked F. F.

or two-to-three block, depending on the proportion of auricular to ventricular beats.

The electrocardiogram has given physicians an insight not only into the presence of this condition, but also as to what takes place as it disappears. Instead of the heart at once resuming a normal rate, as in paroxysmal tachycardia, the excess of P waves disappears first, leaving a condition of paroxysmal tachycardia. A state of auricular fibrillation which will be described later is now assumed. In the end the normal rate is resumed.

Although paroxysmal tachycardia is a matter of days in duration, auricular flutter lasts longer and sometimes stretches over a period of months or years. Digitalis is extremely valuable in relieving auricular flutter.

The study of auricular flutter is still too new for anyone to be able to differentiate it from paroxysmal tachycardia in so far as its cause is concerned. It is known, however, that it gives the highest pulse rates and that it has a different method

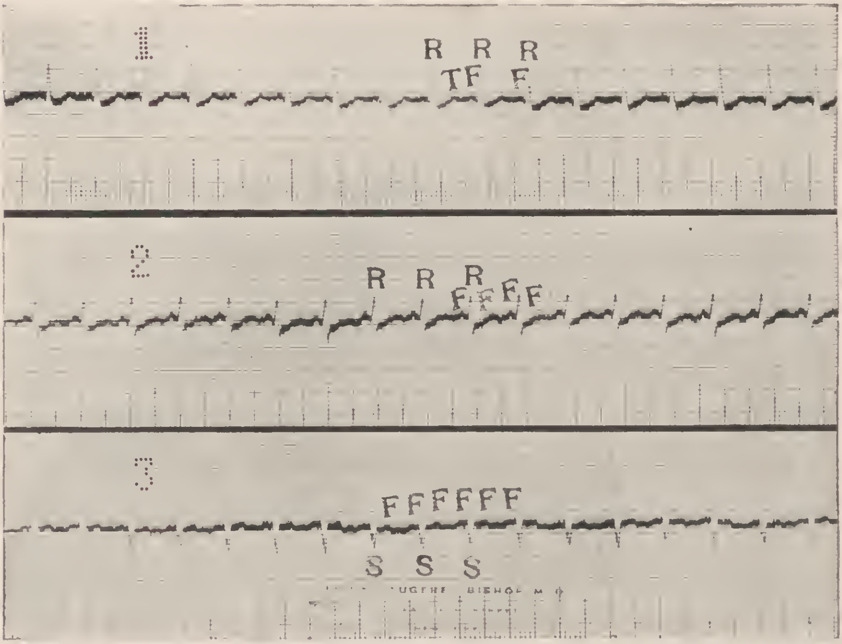

Fig. 25.—Electrocardiogram illustrating auricular flutter (f,f,f). The auricles are beating 300 times a minute and the ventricles are beating at half this rate. The ventricular waves indicate left preponderance.

of offset and probably of onset from paroxysmal tachycardia. It occurs in the same type of individual.

Recent study on auricular flutter which is being carried on entirely by the aid of the electrocardiograph promises some very interesting facts in the near future.

CHAPTER X

AURICULAR FIBRILLATION

INSTANCES OF TREMBLING PARALYSIS OF THE AURICLE

The condition of trembling paralysis of the auricle is clinically known as auricular fibrillation. This remarkable condition seems hardly compatible with life and yet people may have it

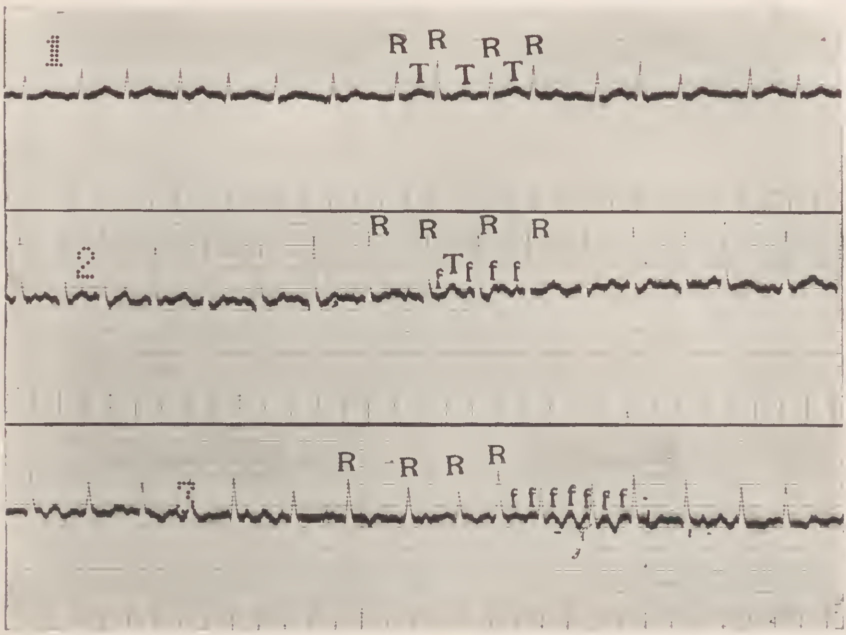

FIG. 26.—Record illustrating auricular fibrillation. The small waves marked f,f are due to fibrillation of the auricles. The ventricular waves are seen to be irregular and rapid. They occur 130 times a minute.

continuously for decades. In this state the auricle has lost all semblance of orderliness, the influence of the pace-maker is gone, and even various abnormal contractions of the auricle heretofore described, are no longer recognized. In their place there has been set up a tremor which comprises countless fibrillary twitchings, and even these are not orderly. They arise apparently from myriads of foci throughout the auricular

tissue. The record of these twitchings reminds one of the tracings of a seismograph, which records the tremblings of distant earthquakes.

What type of a picture, then, can one expect from such a disturbance? Instead of a normal or even abnormal P wave, as found heretofore in other auricular contractions, there are no P waves at all, but merely countless little tremulous lines, each of which is a record of a tremor. There is nothing the matter with the conduction of each of the impulses down toward the ventricle and as a result they all crowd upon the connecting

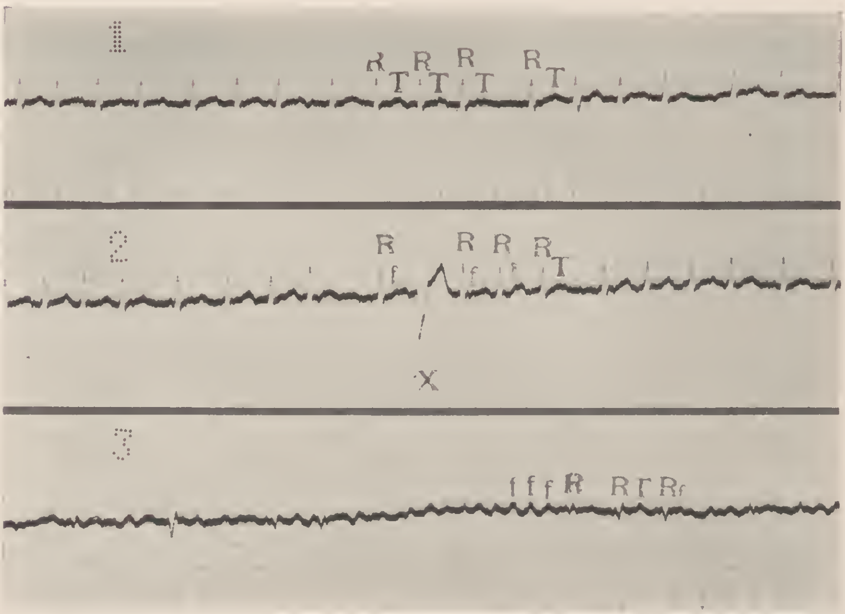

FIG. 27.—Record of another patient, which illustrates auricular fibrillation. The f,f waves are seen running throughout the record. The ventricles here are very irregular. There is a ventricular premature beat in Lead II.

bundle, each one eager to get through. It has been estimated that there are five-hundred or more of these each minute, or about ten every second. Since there is no disturbance of the ventricle, it does its best to oblige, but just as in auricular flutter, it cannot keep up such a pace. Since these twitchings represent impulses of different strengths, the ventricle receives correspondingly varied stimuli. Its response to these is, therefore, varied as to both size and frequency. For example, a strong stimulus will incite it to give a strong beat. A half

a dozen or more stimuli falling upon the ventricle find it refractory while it is beating. Once it has recovered and rested from this beat the next stimulus to which it can react may be very weak, so that the ventricle will give a small beat. This popular explanation conflicts with the theory of total response. But if this little book proves a key to the subject the reader will be in a position to follow it into more technical literature.

The electrocardiogram of auricular fibrillation will show at the beginning a total absence of P waves for which the tremors, described above, are substituted. R-T waves of widely varying

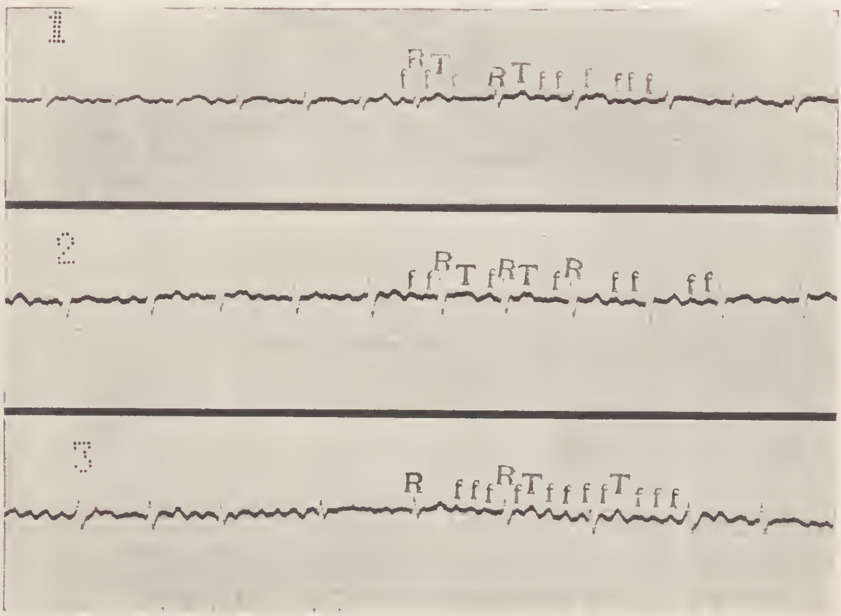

FIG. 28.—In this record the waves due to auricular fibrillation (f,f,f) are very plain and there is a slower ventricular rate.

size occur and in absolutely irregular rhythm. Since the ventricle is not altered they are similar in shape. Although it is sometimes very difficult to distinguish this condition clinically from frequent extrasystoles, it can be diagnosed at a glance in the electrocardiogram. Auricular fibrillation occurs chiefly in damaged hearts. Ventricular extrasystoles may occur with it, though never auricular extrasystoles. This condition is recognized by the entirely different shape of the R-T waves.

Fibrillation is considered by many as evidence of a myocar-

ditis. Sometimes it may be transient, as after extreme exercise of a damaged heart or during pneumonia. The tendency to it usually remains after it has once set in.

Digitalis is more valuable in this heart condition than in any other. One can attempt to block as many impulses of the heart as possible at the connecting bundle with digitalis. Thus, the ventricle is spared excessive stimulation. Since it is known that digitalis must not be given as a rule in cases of frequent

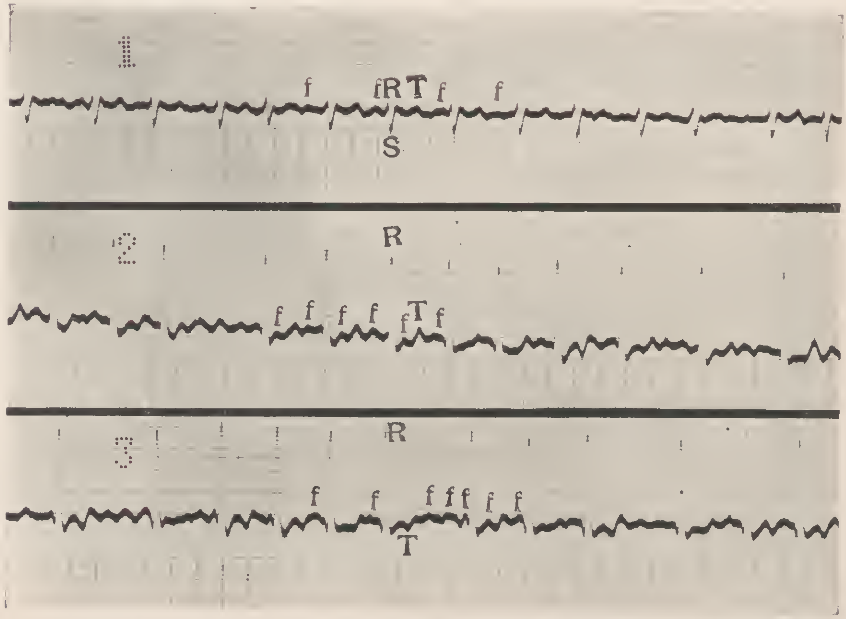

FIG. 29.—Record of a patient who had auricular fibrillation. The fibrillation waves (f,f,f) are plainly seen where they are marked and at many other places in the record. The right ventricular preponderance is shown by the large size of the S waves in Lead I.

extrasystoles it is extremely important that one should differentiate between these two conditions. It is in this connection that the electrocardiogram gives a clear vision as to our course, rather than to leave it to hazardous chance.

CHAPTER XI

ALTERNATION OF THE PULSE

This condition is otherwise spoken of as Pulsus Alternans. Although it is a very serious disturbance it has been extremely rare in my own experience. It is manifested by large and by small beats of the heart regularly alternating with each other. It is usually discovered in the blood pressure examination by auscultatory methods. At a certain level of pressure every alternate beat only is heard. Occasionally it is said to be observed in electrocardiograms. I have no example of it in my own collection. It is said that the P, R, T, waves look all alike except for the height of the alternating R, T waves. My own belief is that the phenomenon has a good deal to do with the tonicity of the peripheral blood vessels, rather than with the heart beat itself. This would explain the absence of evidence by the electrocardiogram. There are certain electrocardiograms in which there seems to be lengthening of the R and T waves, but they must be of a different type, as they do not correspond clinically with the pulsus alternans cases, which, in our experience, have always been observed in exhausted hearts. From a clinical standpoint, pulsus alternans runs only with severely damaged hearts.

Paul White, in his study of this condition, says: "In regard to a definition of the term, pulsus alternans is used to indicate alternating beats which are unequal in force and volume. The inequality is due to the unequal development of pressure in the left ventricle. The inequality of the beats at the radial artery is appreciated at times by palpation alone. It may also be detected on taking of blood pressure at the brachial artery. A graphic tracing of the radial artery shows the condition best. The electrocardiogram does not show pulsus alternans, even when it is distinct in the mechanical tracing. There is a type, however, which can be detected electrically. When the R wave or the T wave is tall, the mechanical wave is short, or the condition may be reversed. In the mechanical type there

is not alteration of rhythm, and the distance between the beats is regular. Pulsus alternans usually arises from the left ventricle, but it can also have origin in the right ventricle or the auricles.

"Two explanations have been advanced as to the cause of this irregularity: (1) It is supposed that the muscle fibers of the ventricle are not capable of contracting with equal force at each systole; some portion failing at alternate cycles; perhaps some portion or another of the muscle is defective. (2) Another view is that the heart, as a whole, is defective in contractile power and defective fibers are widely distributed. If the first explanation is true there ought to be more electrocardiographic evidence. Statistics show that the age incidence is less in persons under forty (15 per cent. of cases); and more common over 50 (62 per cent. of cases). In cases examined with regard to hypertension, it was found in 51 per cent. of hypertension patients. It is also found in association with acute infectious disease. The prognosis is serious. The treatment is that of the underlying condition."

A. E. Cohen is in agreement with Paul White as to the comparative frequency of this finding.

An explanation of the relative infrequency of pulsus alternans in my experience, as compared with that of other writers, Cohen and Paul White, for example, is that they quote statistics from hospitals where the staff is constantly on the watch for such phenomena, and the internes have the patients under constant observation, bearing this condition in mind. They may find alternation as an occasional incident, and report the whole case as one of pulsus alternans. A gentleman, who consulted me, and who arrived after a long motor ride, and who had suffered myocardial damage, showed a picture of bundle-branch-block in his electrocardiogram, but might not have shown alternation under other circumstances, when not under strain of fatigue. The classification of cardiac irregularities under the tutelage of Lewis, into seven varieties, includes pulsus alternans. In my own teaching, I have found it burdensome to carry this seventh type, because of its very limited application in my own experience. This is one reason why I should like to see the question opened up to have a consensus of

opinion on the importance of this phenomenon, and whether it is worth while to carry it still as one-seventh of the classification.

Perhaps the time has come for a new classification. In the present state of dissemination of knowledge of the electrocardiograph by the profession, it would seem to me good policy not to vary our teaching until we know a good deal more about it.

CHAPTER XII

THE EFFECT OF VALVULAR DISEASE ON THE HEART AS SHOWN BY THE ELECTROCARDIOGRAM

Thus far both normal and abnormal contractions of the auricle in response to stimuli which travel through their walls have been spoken of. These contractions have given us such distinct curves they could readily be recognized. The heart valves, which are but reflections of the thin inner wall of the heart, have no muscular tissue in them and therefore set up no waves of their own. It can only be said that the electrocardiogram is helpful in valvular disease of the heart because of the secondary changes which occur in the heart muscle. Such electrocardiograms are indeed very useful. Since they are secondary evidence, however, one must not ask too much of them but merely take these electrocardiograms of valvular disease for what they are worth, which after all amounts to a great deal.

Mitral Stenosis. In mitral stenosis it can be truly said that the electrocardiograms are frequently diagnostic of the disease. Since the left auricle must contract powerfully to send the blood through the small stenosed mitral valve, the P wave which represents the auricle may be much exaggerated. It may be several times higher than normal, or perhaps broader and sometimes notched, or again it may have a flattened plateau-like top. In most cases of mitral stenosis of long duration there is a preponderant enlargement of the right side of the heart. All these indications appear in the electrocardiographic picture. In the first lead instead of an upright R wave there is an inverted peak and an exaggerated P wave followed by R waves indicating right sided preponderance, strongly suggestive if not diagnostic of mitral stenosis. Many cases of mitral stenosis are associated with auricular fibrillation. In these instances the exaggerated P waves are replaced by exceptionally large oscillations. Oscillations of great amplitude are seen only in mitral stenosis.

Aortic Disease. In aortic disease the electrocardiograms give no constant curves. The auricles, being usually unaffected, inscribe normal P waves. Both the right and the left ventricles are usually thickened but, since the left side nearly always predominates, an upright R wave is chiefly found in the first lead, and an inverted peak in the third lead. It is interesting to note in this connection that a large excursion of the R wave and a small or inverted T wave in Lead II are quite frequent.

Mitral Regurgitation. Mitral regurgitation gives no characteristic curves in the electrocardiogram.

Pulmonary Stenosis. Pulmonary stenosis may be mentioned in connection with mitral regurgitation. There is always a right sided predominence in pulmonary stenosis and very often enormous amplitudes of excursion to the R wave are shown in the electrocardiogram.

Congenital Defect. The diagnosis of congenital defect is almost certain when the R wave is found to be many times its normal height and is so placed as to indicate right sided predominance.

Dextrocardia. Dextrocardia is another cogenital defect that must be mentioned. In this condition the heart, as well as other viscera, is transposed to the opposite side. Here, the heart may be working perfectly normally and so give no evidence of either auricular or ventricular disturbance but the electrical currents will be reversed and as a result Lead I will often be normal excepting that it will be invariably inverted. Clinically it may often be difficult to distinguish dextrocardia from cases in which the heart has been mechanically pushed or pulled over to the right side, but electrically the diagnosis can readily be made because when the heart is pushed or pulled over to the right the electrocardiograms show normal leads.

CHAPTER XIII

LESIONS IN THE RIGHT BUNDLE BRANCH

The most striking example of definite, demonstrable, scientific value, when we have excepted the recognition of the six cardiac irregularities, is found in those people who have suffered a definite, localized damage to one of the branches of the bundle of His. This very often is the direct result of rupture, thrombosis, or embolism of a vessel of the heart, the occurrence of which is frequently revealed in the history of the person by the story of an attack characterized by severe cardiac pain of long duration, with very marked heart failure from which the person gradually recovered. As in the corresponding cerebral event, the lesion may be, and often is, thrombosis, sometimes it is an embolism, and occasionally a rupture.

The relative frequency of this condition, in that group of people whose cardiac condition is of sufficient importance for them to seek a complete technical examination, is about 3 per cent., thus showing that cardiac disease is usually allowed to advance to a high degree of development before people receive the benefit of a close analysis of their heart condition.

In a group of 20 people who were suffering from this disease which involved the terminal branches of the bundle of His, all but three were over fifty years of age, and all but four were males. The duration of the disease previous to the time when the patient came to my office, was nearly always considerable. In only four patients was it less than a year.

The prominent symptoms of which these people complained were precordial pain, dyspnea, and palpitation. Pain of some sort was present in all but two of these cases and was sharp and severe in eleven. Sometimes it was described as a sense of soreness or a dull pain or a feeling of oppression. The situation of the pain was variable, but nearly always included the precordium, at least in part. In five of the patients the first symptom of disease was pain, while in four the first symptom was shortness of breath. In the remainder of this group the sypmtoms

had rather an insidious onset, and it was difficult for the patients to say of what they first complained.

Although dyspnea is usually a prominent symptom, there was one of these people in whom it was not present and another in whom it was noticed only at night when it came on in attacks.

Palpitation appears in attacks on exertion. It was present in eight of these persons. When present it is usually a distressing and prominent symptom.

Edema, strangely enough for a condition which is usually considered as serious, did not occur very frequently, and when

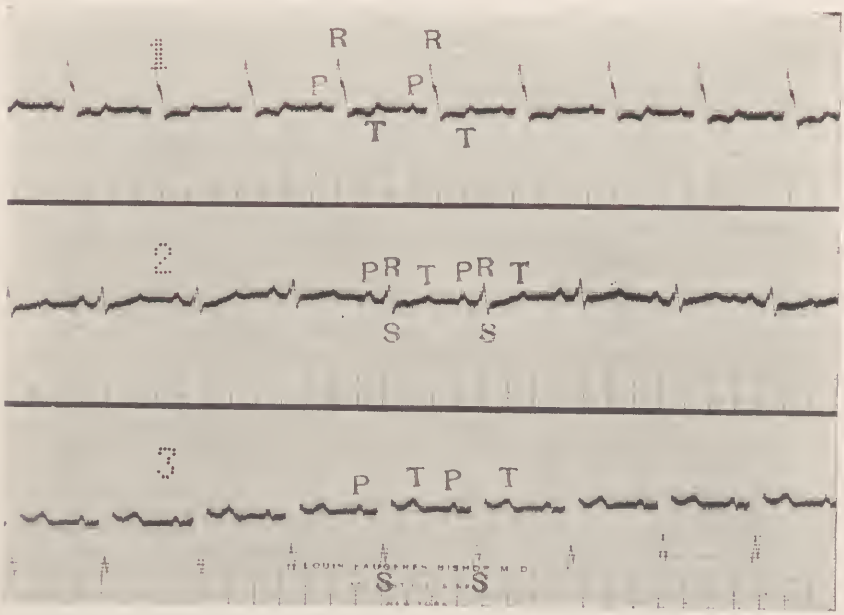

Fig. 30.—This illustrates the waves due to intraventricular block with blocking of the right bundle branch. The notching of the R waves in Lead I and of the S waves in Lead III is very plain; also the width of these waves.

present was not marked, except in one person. Fifteen of these people did not show it.

The weakness of the heart tends to cause a congestion of the lungs which is manifested in cough and this was present in about half of these people. It was not severe, but was very persisent.

When these people were examined, the most evident thing about them was their age. In going over their records, it is also evident that the majority of them had increased blood

pressure, although it it true that some did not show this. Blood pressures in this series were observed as high as 220 mm for the systolic, and 12 of these people gave figures for the systolic which might be considered above normal.

The heart rate was usually not rapid when they came for examination, being over 90 in only six patients, and in only one person was it very rapid, being 120 in that case.

The electrocardiographic record shows the changes which are considered as typical of an obstruction in one of the

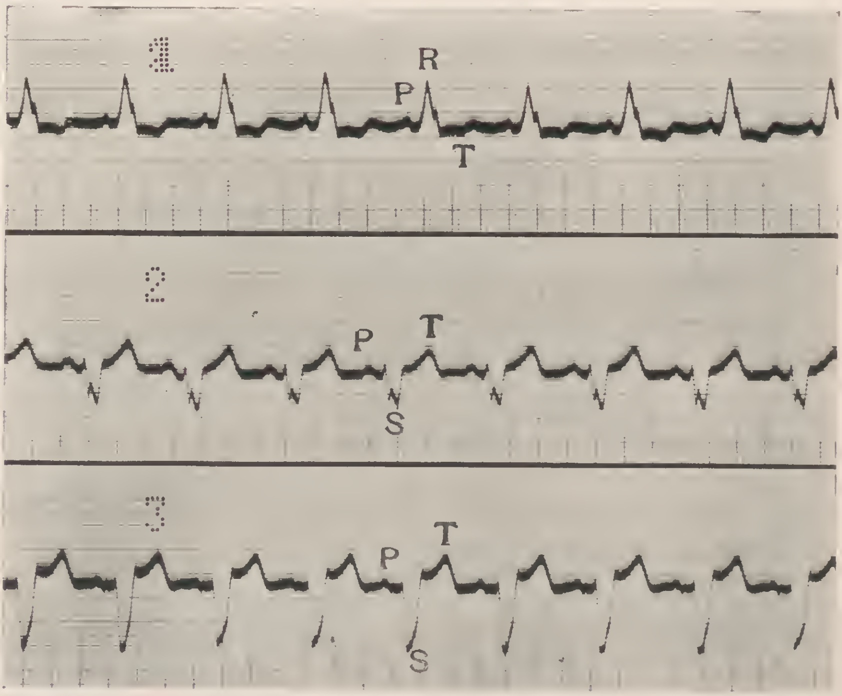

FIG. 31.—Another record to illustrate intraventricular block with a right bundle branch lesion. In this record the notching is not so plain, but nevertheless can be made out. The width of the abnormal waves, the R. and S. waves is plain enough.

branches of the bundle of His, in all of these people. The ventricular waves have the large notched Q, R, S group with increased width and the large T wave in the opposite direction, which is typical. All but three of them have the Q, R, S, deflection, chiefly upward in Lead I, and downward in Lead III, so that the lesion may be said to be in the right branch of the bundle. The other three records probably indicate a lesion in

the left branch of the bundle. One of the records shows the person had auricular fibrillation, but in all the others the normal rhythm is in force. Three cases show premature ventricular beats and one shows a prolonged conduction time between the auricles and ventricles—an example of partial heart block.

The *x*-ray pictures which were taken of these people by the teleoroentgenographic method show that four of them did not have an enlarged heart. Five of them had extremely large hearts and in the remainder there was a moderate enlargement.

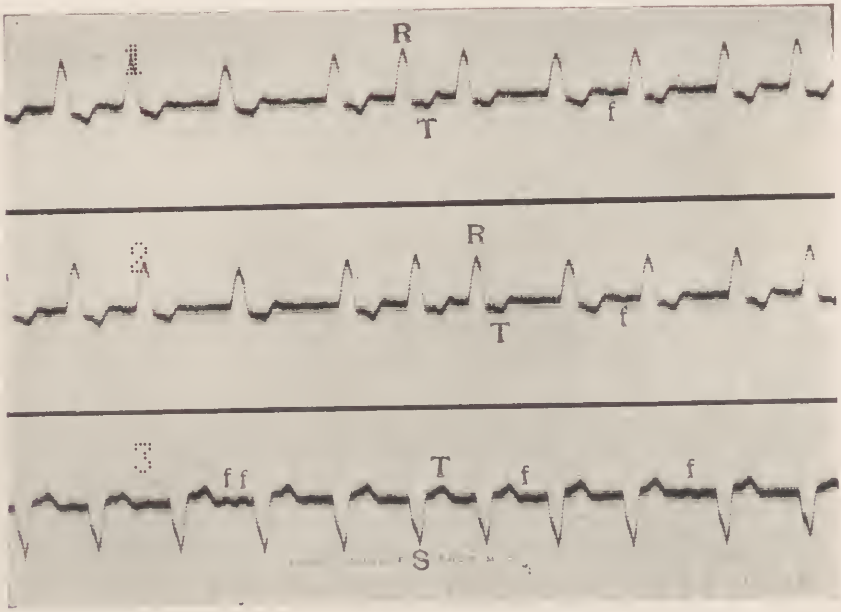

Fig. 32.—A record of a patient with auricular fibrillation as well as intraventricular block of the right bundle branch type. The R and S waves are unusually wide but the notching is not very plain. The fibrillation waves are indicated by f,f,f.

It is a very interesting finding that eleven of these patients were considered to have normal valves and in four of them both the aortic and mitral valves were diseased, while in the remainder only one valve was affected. Eight people showed systolic murmurs at the apex which were not considered to indicate valvular disease.

In our attempts to treat these people, we have been able to observe the response to digitalis in 16 of the 20 persons and have found that in seven of them it had an extremely beneficial

effect. Four were only moderately benefited by digitalis and in five the response was poor.

It has been said that all of these people are persons who are well advanced in years and so it is not surprising that our clinical diagnosis, after having reviewed all of the findings, should be arteriosclerosis in eight, cardiosclerosis in one other, and angina pectoris in still another. This indicates that these people were suffering chiefly from a condition which goes with age and is not especially brought on by any acute disease.

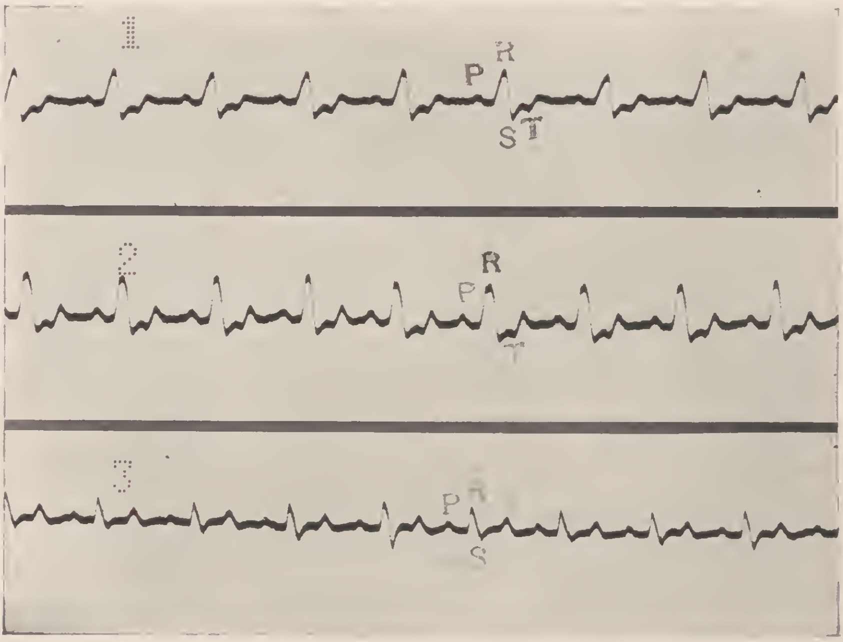

FIG. 33.—A record that shows intraventricular block by the width of the R waves, but is not typical of either right or left bundle branch lesion.

Five of them were classified under the diagnosis of myocardial degeneration, while four were believed to have primary valvular disease. In the one remaining person, our diagnosis was cardiac dilatation.

Several of these people, and curiously not those who showed the most striking electrocardiographic pictures, were able to pursue their vocations in a manner equal to the average of their age.

All these observations were made in private practice, and bear out the belief expressed by at least one of the greatest

heart specialists in the world, that the most fruitful field for the study of cardiology is found in private practice.

The general condition of the heart must be very good indeed when it can survive and make so good a comparative recovery from a definite circulatory accident. It it analogous to the experience that slight attacks of hemiplegia are much better borne and more frequently recovered from among well-cared for people than among a group ordinarily observed in hospital practice.

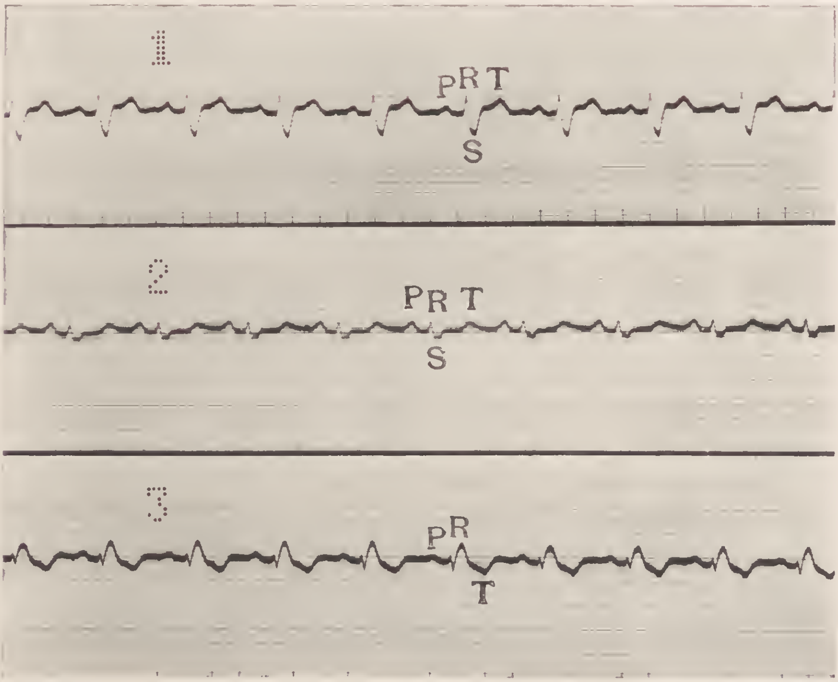

FIG. 34.—A record which shows intraventricular block by the width of the R waves. The notching is not plain. The large S wave in Lead I indicates a left bundle branch lesion.

The most interesting conclusion to be drawn is that accidental interference with the circulatory system of the heart is probably very frequent and is not confined to those showing striking clinical manifestations. It is possible that future studies may reveal some means of recognizing such an accident to other parts of the heart muscle. There is certainly much to learn from the study of such groups as these.

I happened to be looking over Wiggers' wonderful book on

"Circulation in Health and Disease," one day and I ran across an illustration of experimental bundle branch lesion. It struck me very forcibly because only two or three days previously a woman who had been under observation a long time for right bundle-branch lesion, came into the office during an attack of tachycardia, and her electrocardiogram was so exactly like that of the dog, that it struck me as a striking illustration of the class relationship of clinical medicine and laboratory experimentation in cardiology.

CHAPTER XIV

THE ELECTROCARDIOGRAM AS SHOWING RELATIVE ACTIVITY BETWEEN THE RIGHT AND LEFT SIDES OF THE HEART

It is a matter of common knowledge that in many afflictions of the heart the ventricles increase in size. Although it is true that the right and left sides share in this enlargement in some conditions, yet, for example in mitral stenosis, the right ventricle will be disproportionately thickened; whereas in others, such as aortic disease of long standing, or a chronic nephritis with high blood pressure, it is the left side that enlarges the most. It must be remembered, however, that in such conditions both sides of the heart increase in size, although usually to a greater extent in one than in the other.

It has become known that the R-T wave represents the activity of the ventricle, and it can as a result be assumed that if the ventricle is abnormal in size there will be some change in this complex, and this is what actually occurs.

Thus far, little attention has been paid to the three leads, for the disturbances studied in the previous chapters show essentially the same things in all three leads excepting that one may be more distinct than the other. In enlargements of the ventricle one can distinguish between the right and left predominences by a comparison of the various leads.

When the left side of the heart is proportionately increased in size the R wave in the first lead will be steeple-like in shape and it is apt to reach considerable height. In the third lead, however, the steeple, though just as tall, is found to be inverted below the line.

The opposite holds true for right sided preponderance, for here, in the first lead the steeple is inverted, whereas it is upright in the third lead. It is the size of these waves in Lead I and Lead III that indicates the proportion of predominance.

Clinical observation has shown that a large number of otherwise apparently healthy people complaining of some abnormal consciousness of their heart action have shown a relative right predominance and we have taken this to indicate that there was in fact some abnormality of the heart even if it was not always easy to classify. I do not feel, with some clinicians, that be-

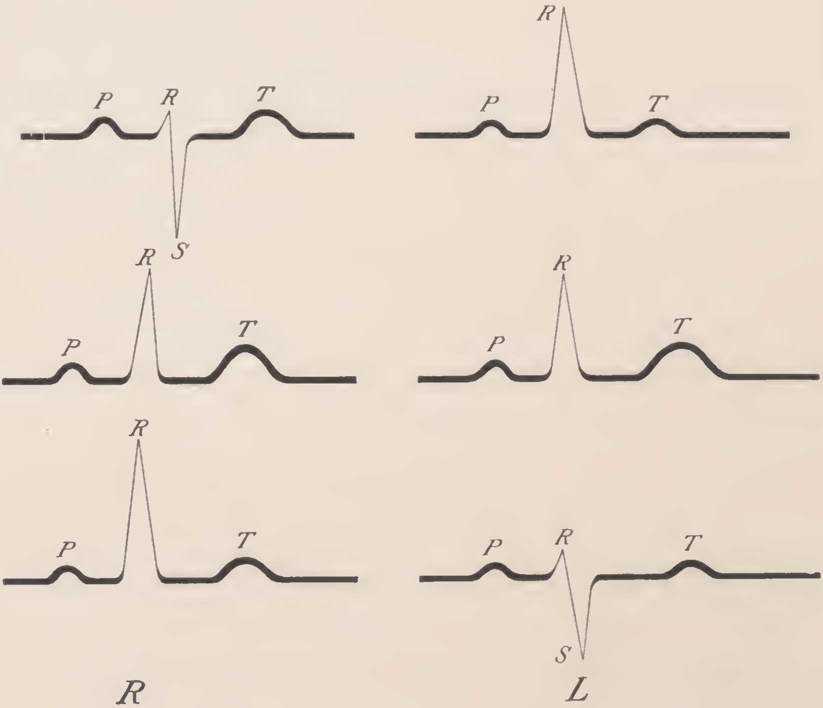

FIG. 35.—A drawing to illustrate the effect of hypertrophy of the right ventricle and of the left ventricle upon the electrocardiogram. R illustrates the effect of hypertrophy of the right ventricle. The electrocardiograph picture in the three leads indicates right ventricular preponderance. L illustrates the effect of hypertrophy of the left ventricle. Right ventricular preponderance is shown by the small R and large S in Lead I. Left ventricular preponderance by the small R and large S in Lead III.

cause preponderance may be due in many instances to certain chance relationship, as to position, it can be overlooked when we are seeking for heart disorders. The point is to give the sign its proper weight.

One point that may be a clinical stumbling block in the matter of judging between right and left preponderance, is that

when the heart as a whole is dislocated, the observations are invalidated, and it is a matter for careful clinical judgment as to how far the observations must be discounted by our consideration of the amount of deformity of the heart. This difficulty might be met if we could in some way make our Leads correspond to the deformity of the heart as shown in the *x*-ray picture. In forming a diagnosis of preponderance the position of the heart must be taken into consideration.

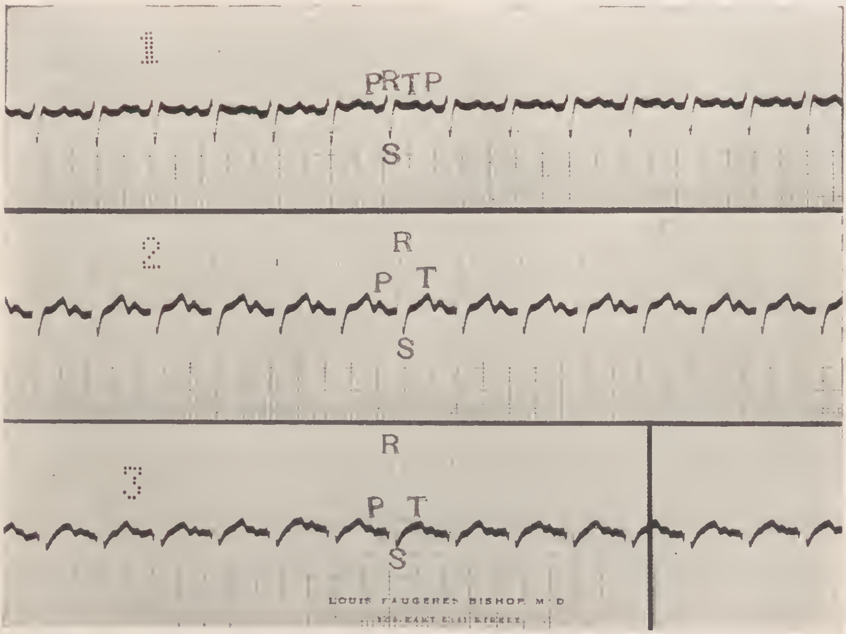

FIG. 36.—Electrocardiogram of patient to illustrate right ventricular preponderance. The small R and large S in Lead I is the determining sign.

In the early days of the electrocardiogram there was considerable question as to whether these curves gave a true picture of the heart enlargements. Sometimes percussion revealed a left-sided hypertrophy whereas the electrocardiogram indicated a right-sided one. Eventually it was found on post mortem examination that the exact science was the correct one and the clinician was wrong.

At times unsuspected conditions may be diagnosed by this method. For instance, a preponderant right heart will lead one to look for other evidences of mitral stenosis in which it is well

known that the classical presystolic murmur may not appear early. Or again, a heart may enlarge considerably in the anteroposterior direction without any enlargement being detected to the left. The electrocardiogram will at once solve this difficulty.

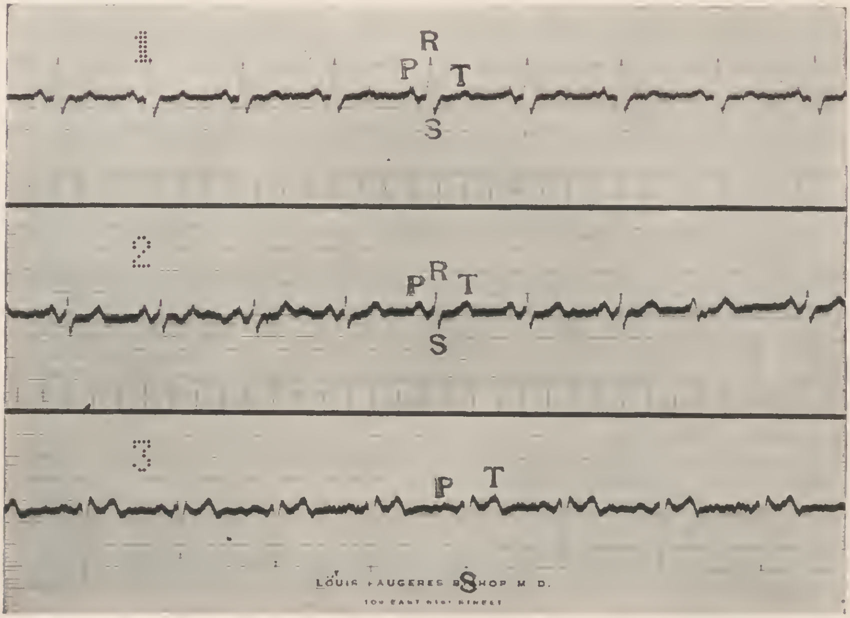

FIG. 37.—Electrocardiogram to illustrate left ventricular preponderance. The small R and large S in Lead III is a distinctive feature.

One feels justified in again emphasizing that, acute as our perceptions may be, one cannot hope to compete in exactness with such physical forces as the electrical reactions. Wisdom may be employed, however, in subjecting these exact methods to our control.

CHAPTER XV

PRACTICAL VALUE OF THE ELECTROCARDIOGRAM

Before the electrograph and other less efficient instruments for recording the heart's action were invented, heart disorders were diagnosed by the senses of hearing, touch, and sight. The finding of a murmur was considered a grave event because there was little else from which to judge what the heart was doing. The physician who studies his cases with the electrocardiogram has come to know better, for he has so much more knowledge on which to base his opinion.

A murmur may be appraised when the following findings are given; a definite heart rate, information as to how the auricles and ventricles are functioning, the state of the conduction system, and whether one side of the heart is relatively larger than the other. Murmurs may help to make a diagnosis or prove mere harmless incidents. Or again, consider a patient with a slow pulse and no other symptom. One individual may have a slow pulse with absolutely nothing the matter with his heart and he may live a long and healthy life, whereas in another person this slow pulse may be a danger signal to inform the physician that behind the slow pulse lies a heart block of the most serious kind. Without an accurate instrument of diagnosis, who can tell the difference?

It is a common bad habit among doctors to trust too much to their memories, or perhaps to scribbled notes. A man with heart trouble, comes into the office. A note as to the size of the heart, its rate and the character of the heart sound, is perhaps made. The patient returns and another note is made as to these findings, and thus a record of the case is kept. Each one of these descriptions, however, must produce in the physician's mind a picture of what the heart is doing. The actual photograph depicted by the electrocardiogram is much more valuable. It is like reading a prospectus of a place which we have never seen and visualizing the place as compared to going there and actually seeing it. There is nothing more valuable in following

a heart patient than to have a series of these prints and thus compare them and actually see at a glance what progress or lack of progress the heart has made.

One of the most important things about the electrocardiogram is the fact that it is a means of controlling the administration of digitalis. It is well known that in many heart disorders this drug is invaluable. Moreover, it has been found that large doses, properly given, are far more effective than small doses, which are frequently almost useless. Digitalis may be dangerous as well as useful, however. As the patient becomes saturated, he develops extrasystoles, then heart block, which finally becomes so severe that the heart stops beating entirely. Before all this takes place, the T wave in the second and third lead of the electrocardiogram becomes inverted, and to those who have the good fortune of obtaining such tracings, it is an indication to watch the drug carefully. One is always in danger of giving too much digitalis without these tracings.

The electrocardiogram is also at times most valuable in the prognosis of heart trouble. For example there is nothing in sinus arrhythymia to worry about, whereas heart block is a grave disorder. Extrasystoles may be compatible with a long life time of good health, but auricular fibrillation, with which they are so often confused, indicates a profound disturbance. This is often the case with many cardiac disorders, the prognosis of which is dependent on accurate diagnosis, which in turn rests on accurate methods.

There is nothing mystical or hopelessly complicated about electrocardiography. It is easy to learn and interpret and requires common sense far more than technical knowledge. The understanding of electrocardiograms is the criterion of modern, sensible, accurate handling of a patient, as compared to the slipshod, casual, though doubtless well-meaning ways of the past.

APPENDIX

THE PRACTICAL EMPLOYMENT OF THE ELECTROCARDIOGRAPH.

CHAPTER I.

THE SETTING UP OF AN ELECTROCARDIOGRAPHIC MACHINE.

1. Place the table in position.

2. Place the galvanometer on the table.

3. Place the resistance box on the right end of the table, or on a separate table.

4. *Tuning Fork.* This is placed on a separate stand at least four or five feet from the galvanometer. (If it is nearer than this, the galvanometer will pick up the make and break of the tuning fork.)

5. Place the lamp stand on the table.

6. *Time Wheel.* This is placed in position on a holder that does not touch the table.

7. *Batteries.* The 8-cell storage battery is best placed in another room, but if inconvenient to do this, it can be placed under the table, beneath the galvanometer; place the 4-cell battery about midway underneath the table.

8. *Camera.* This is placed about 1.5 meters from the galvanometer lens tube.

9. *Connecting the Wires.* Connect the magnet circuit wires to the binding posts on the front legs of the galvanometer.

10. Connect the left hand wire of the magnet circuit through the resistance light, and switch to the positive side of the battery.

Connect the right hand wire to the ammeter and from the ammeter through the resistance light, and switch to the negative side of the battery.

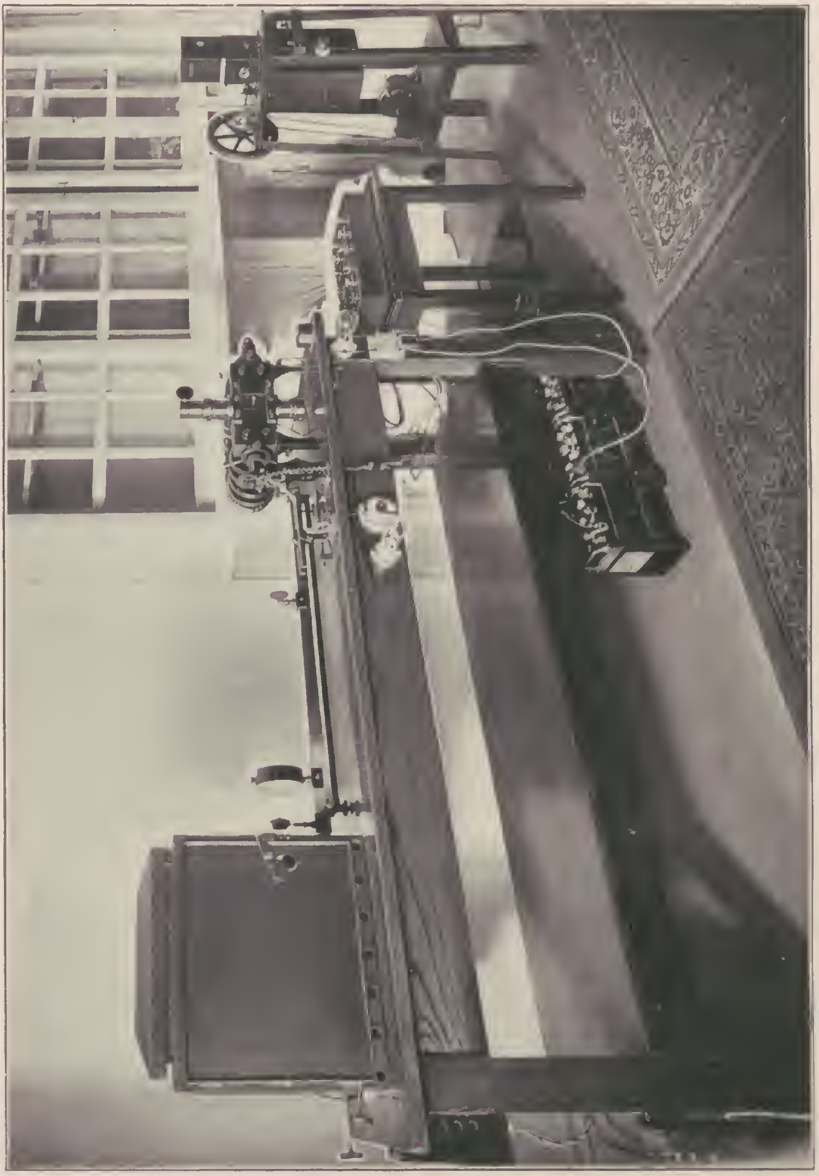

FIG. 38.—The Hindle electrocardiograph.

11. Connect the positive post of the dry cell (which is the carbon) to the post marked + on the resistance box.

Connect the negative post of the dry cell (which is the zinc) to the post marked — on the resistance box.

12. Connect the lower post of the galvanometer housing (with insulated lead-covered wire) to the right hand post on the resistance box, marked "galvanometer;" and the upper post of the housing to the left hand post on the resistance box, marked "galvanometer." The lead covering of both these wires

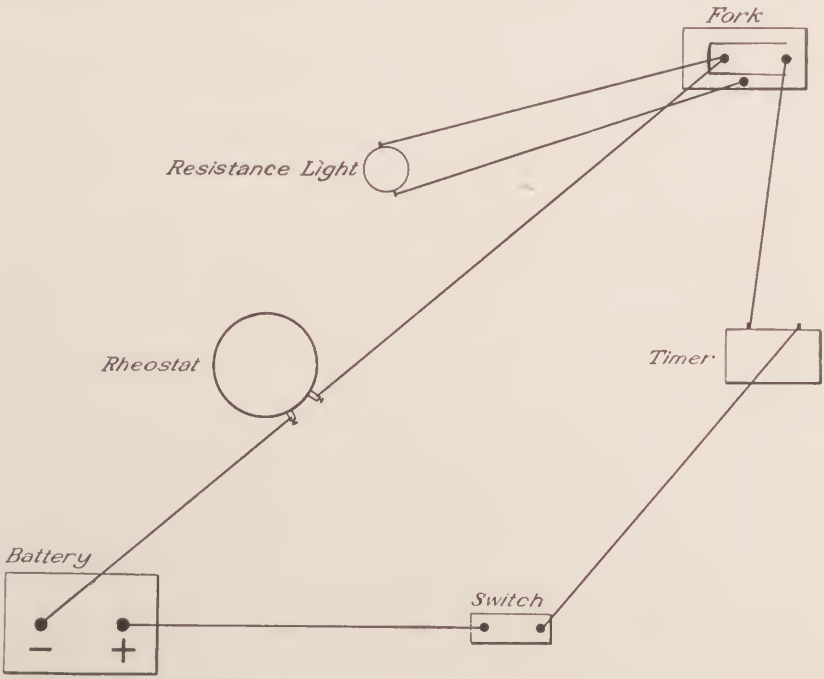

Fig. 39.—Diagram of wiring of tuning fork and time wheel.

should be carefully grounded, and great care should be taken that the lead covering of the wires does not touch the posts of the housing or the posts of the resistance box. To prevent this happening, pass the wire through a glass bead, so that the bead is between the post and the lead insulation. The lead covering of all these wires must be carefully grounded.

13. *Tuning Fork and Time Wheel.* The diagram shows how the tuning fork and time wheel are connected.

14. *Arc Light.* The arc light should be placed in the lamp

house. The connections from the main should be made by an electrician. To a 15 ampere, 110 volt, direct current with circuit, fuse the switch, using the polarizing connector furnished. The housing of the arc light should be carefully grounded, on account of the make and break of the arc light, or else, when the arc light breaks the current will affect the galvanometer.

15. *Camera Motor.* Connect the camera motor to any convenient lamp socket. See that the drive belt is running true and not slipping, otherwise your timing will not be correct. After putting the film in the box before putting into the camera, be sure it runs free. This can be ascertained by spinning the button which screws in the end of the shaft outside of the box. Be sure to turn it the right way or you will unwind the film.

16. *The Three Leads.* The patient's Lead wires are to be connected directly with the resistance box to the three binding posts marked L. A., L. L., and R. A., respectively. The wires used must be insulated and lead-covered. Do not use too small a wire. The patient's Leads should be strung direct from the resistance box to the patient, keeping them as far as possible from the timing wheel, the vibrator, and the arc light, in order to avoid picking up the make and break of the frequency current. All unnecessary breaks in the connection, such as plugs, etc., are to be avoided. The wire should be continuous.

Where the wires join the contacts connected with the patient, no flux or acids must be used in soldering. These connections must be carefully inspected to be sure they have not come loose. If they do the cardiogram will be very poor.

Always use an insulation, such as a glass bead, between the lead covering and the contacts. This is particularly essential at the posts of the resistance box. The connection with the resistance box should be taken off occasionally and carefully cleaned by scraping. Do not use sand or emery, as the particles are apt to stick to the metal and prevent a perfect contact. The electrodes must also be kept clean and polished. Do not use an acid or alkali polish. A dry powder, such as "bon ami," is preferable.

The simplest way to clean the contacts in the resistance box is to take a good piece of dull finish writing paper and place it between the brush and the contact. Move the brush backward and forward, and then, holding the brush in place, pull the paper

between the brush and the contact a few times, which will leave a clean polished surface.

17. *Ground Wire.* A size 8 or 10 copper wire should be connected and soldered to a clean place on a running water pipe, and used as a ground wire. Failure to do this will, without exception, cause the strings in the galvanometer to break. If the apparatus is to be used where alternating current only is available, special precautions are to be taken against induction, in order to avoid accidents.

The solution of this problem is to have a copper plate covered with carbon buried in the ground, and have the wire soldered to it, deeply enough so that it is well grounded. In this way a perfect ground will be obtained.

The Galvanometer. The galvanometer is symmetrical in its construction and either microscope may be used for projection, as may suit conditions in the laboratory. The insturment is very rigid and unless located where there is an unusual amount of vibration, it can be used standing on a substantial wooden table. Have the table adjusted, so as to stand level and solidly on all legs in the exact position which it is intended to occupy. If possible, have the table legs secured by angle irons to prevent shifting.

To put in the string, remove the wedge from between the pole shoes by taking off the top of the two bronze bars in front. *The wedge is held up by the bar and must be supported with one hand when this bar is removed, otherwise it will fall.* The string house at the top and bottom of the pole shoes may be opened by turning the revolving gates with the fingers.

Insertion of the Lenses. Unscrew the forward and rear microscopes until they can be removed. Underneath these will be seen springs whose action, with that of the nuts, moves the microscopes. Ball-bearing thrust collars will be seen which may come off with the nuts or remain on the tube. The nuts should be removed and laid on a clean piece of paper. The front microscope tube (the one towards the lamp) may now be removed and the 4 mm. achromatic objective screwed into it. The tube can now be replaced and the spring, thrust-collar, and nut put into place. The range of the adjustment screw is sufficient so that it acts as both a coarse and a fine adjustment. Screw the tube in until the face of the objective is about even with

the corresponding pole face. The string may now be put in before the other microscope is in place. The other microscope is the projector and will carry the objective and the projection ocular. The microscopes fit closely in their sleeves and care should be taken to prevent dust and grit from getting on them while they are out. Lay them only on clean glass or paper. Once in place they will not have to be removed.

Inserting the String. Before puting in a string, it may be well to practise the manipulation, using a fine copper wire soldered to pins similar to those on which the strings are mounted. The strings are furnished soldered to brass tips and clamped upon a special mounting board. They are preserved in glass tubes. It is well to repeat the operation of taking the practice wire off the carrier and inserting it in the instrument a few times in order to become familiar with the handling of the manipulator, etc.

Strings are handled with a manipulator which can be clamped upon the tips before they are released from the clamps on the board. Clamp the manipulator firmly upon the pins just beyond the flat plates to which the string is soldered and so that the soldered faces are toward the handle of the manipulator. This will bring the soldered faces toward the operator when the string is in the galvanometer. Unclamp the string from the board and adjust the tension screw of the manipulator, so as to take up the slack of the string. This is done to prevent its coming in contact with the pole faces in insertion.

Tension of the String. If the string can be seen to quiver when lightly blown upon or when the hand is moved near it, it is about tight enough.

Putting the String in Place. Unless the practice wire has been used, it is well before transferring the string to the galvanometer to make sure that the string clamps in the instrument are approximately central and not too far back, so that the string will not come in contact with the pole faces.

It is well to adjust the string clamps as far forward as possible, proceeding as follows: In each of the string houses will be found four milled screws. Loosen the four side screws slightly. Screw the front ones out, and follow up by turning the rear ones in. Do this until the brackets are as far forward as possible. *Do not allow the adjusting screws to be taken out*

or to become too far removed from contact with the slides, as they are often difficult to put in again. With the suspension brackets in this position, it is quite easy to insert the string. Slip the string into place, and if the pin should stick in going in, move it up and down slightly. When back in the slot, tighten the string pin clamp screw—the lower one first. Use the small screw driver supplied for this purpose, inserting same in the lateral openings in the string houses. Keep a firm hold on the manipulator until you are sure that both pins are quite secure. Now remove the manipulator by unscrewing the thumb screws on the arms of the manipulator.

Centering the String. The string must now be centered. Unless the string is accurately centered between the pole faces, it will not be possible to tighten and loosen it without having it go out of focus. If the lack of centering is considerable, it may not be possible to deflect the string without change of focus. When it is properly centered, it may be deflected to the extreme edge of the field or tightened and loosened over the entire working range without material change of focus at zero.

Working Light for the String. On account of the extreme fineness of the string, it must be illuminated in order to be seen by the unaided eye. Use an incandescent lamp, with a small half shade brightly polished inside and set upon an adjustable stand before the instrument, as a source of light in manipulating the string. By moving this light up and down and sidewise, different parts of the string can be so illuminated as to be plainly visible, even fibers as small as one micron. Do not try to see the entire length of the fiber at once, but illuminate first one end and then the other. Illuminate the upper end and looking in from in front, adjust the lateral centering micrometer until the string is seen to bisect the space between the pole faces. Do the same at the lower end. To adjust in the anteroposterior direction, look in through the lateral opening at the top, through which the screw driver was inserted in clamping the string, and adjust until the string is opposite the pole face. At the bottom, it is not possible to look in directly, because the magnet is in the way, but a small mirror such as that of a laryngoscope, held at a suitable angle, and looked at from in front, will enable one to see the string from the lateral aspect, provided the lamp is in proper position. It is to be adjusted in the same way as the

upper end. After the string has been centered with the pole faces, adjust the lamp, so as to illuminate the middle portion of the string. Looking through the hole in which the rear microscope belongs, the illuminated string can be seen against the condenser lens as a background. The microscopes have been adjusted at the factory and the string will appear to bisect the lens. In the event of their having been moved in transportation, adjust by means of the centering screws until the string appears, as mentioned before, to bisect the microscopes.

The other objective is now put in its tube and inserted in the galvanometer. In inserting the tube and lens with the string in place, take care that the spring does not catch and cause the objective to rebound against the string. Screw up both fine adjustment nuts until the objectives are near the string. The microscopes operate about 1 mm. from the string. Stops are provided to prevent touching. Adjust the illuminating apparatus, so as to throw light through the front microscope (condenser) and, using the centering screws, adjust the other microscope until light comes through. This can be most easily seen by holding a white card about a foot from the projection microscope. Cautiously focus the rear microscope in and out, and if the front microscope is properly adjusted to be central with the string as described above, the shadow of the string will presently appear. The projection ocular may now be put in.

CHAPTER II.

RUNNING THE MACHINE.

Focusing the Lenses. In focusing the lenses it is an essential thing to have a perfect alignment. To obtain this we have to remove the front lens of the microscope, and get the shadow of the string exactly in the center. The shadows of the circles seen must also be perfectly centered. The front lens of the microscope can then be replaced and screwed in until the shadow of the string is obtained.

If no shadow of the string is seen now, it is because the alignment is still at fault. The prismatic colors around the circle of light will tell this defect, and by moving the microscope in different directions until the circles are perfectly even, and the coloring the same all the way round, it is possible to get a correct centering.

After the shadow of the string is obtained, one should observe the coloring of the prismatic shades. The best results for a photograph are obtained when the inside circle of the colors is a purple one. The diaphragm is then cut down till the light just covers the slot in the camera. You now move the shadow of the string until it is passed all the way across the lens of the camera, then reverse the current and pass it back in the other direction. The shadow should be of the same density in all positions. If this detail is not correct, one gets a very poor film. If the string does not appear of the same density in all positions, it is because it is not perfectly perpendicular in the housing, and the front and back of the microscope are not in perfect alignment.

A denser shadow of the string is obtained, and also much greater leeway in focusing, if you set the tension of the string so that it moves exactly 1 mm. when 1 millivolt of current is added. Then remove the projector and move the camera away from the microscopes until 1 millivolt moves exactly 1 millimeter. If this is carefully attended to, there is much greater leeway and this adjustment can be run for months without any

trouble with the focusing. A very much more exact reading of the excursions of the string is possible.

The Timer. In connection with the timer a tuning fork is used. This is done because the vibrations of the fork give an exact make and break which gives a rhythm for the time wheel. The vibrations regulate the lines to one twenty-fifth of a second. The tuning fork should be set up on a separate table, otherwise the string will be disturbed by the tuning fork vibrations. The fork is so adjusted that it starts automatically when the switch is turned in. There is very little trouble in keeping the timer in operation. If the spokes of the timing wheel are shortened so that the shadow passes only part of the way across the film, the short shadows of the spokes do not interfere with the reading of the electrocardiogram.

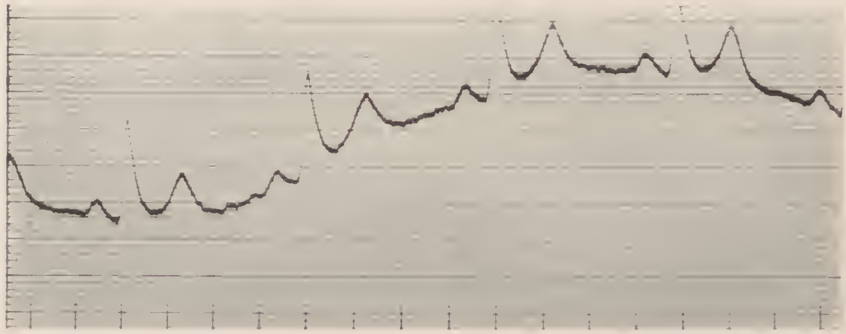

FIG. 40.—Irregular curve indicating broken Lead wires: the broken ends, however, being in contact.

Arc Light. If the arc light is used, the metal box inclosing it should be carefully grounded, otherwise when the arc light breaks, the current will affect the galvanometer.

Failure to get Current from the Patient. Another accident, which is fairly frequent, is a failure to obtain the current from the patient and record it in the galvanometer.

The reason for this is that the Lead wires have become wholly or partially broken where they bend near the contacts. This gives rise to a very misleading state of affairs, because where the wires are not entirely broken, the current may pass and it may not. This depends on the position of the wires. If the broken ends happen to be touching, a partial current comes through. This occurrence causes a special action of the galvano-

meter. The current appears very sluggish and has the appearance of over shooting. (See Fig. 40.)

As will be seen by the illustration, the shadow of the string goes up too far, and travels too slowly.

This same appearance will manifest itself if you have neglected to turn the patient's currents completely in on the protective resistance. This means that the patient's currents are not getting through.

Corrosion of the Lead Wires. The Lead wires, where connected with the control box, are apt to become corroded. They should be taken off at least every two months, and scraped. This will avoid a peculiar appearance in the galvanometer chart.

Testing the Machine. In testing out the machine, to see if it is running in perfect order, before one puts the patient in

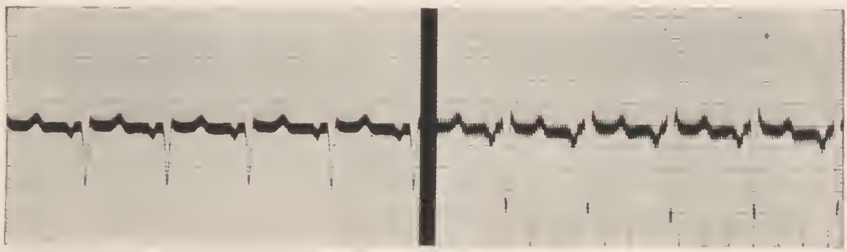

FIG. 41.—Testing the machine; effect of winding of a wire carrying an interrupted current around a lead wire. The curve from the straight wire is shown on the left, that from the wound wire is on the right.

connection with it, the two arm contacts are placed one on the top of the other, and kept tightly together by using a wooden clothes-pin. Then Lead I is turned in. When this is done there should not be any movement apparent upon shadow of the string. Next 1 millivolt of current is added and the tension of the string is adjusted until 1 millivolt moves 1 centimeter. Without changing the tension of the string, test Lead II and Lead III in the same way. They should read the same.

Other factors which may cause differences between the Leads are: dirty contacts; corroding contacts; neglect to wash the bandages perfectly after being used.

CHAPTER III

CORRECT OPERATION OF THE MACHINE WITH THE PATIENT CONNECTED.

Before detailing the steps of the procedure of operating the machine, a word may be said here as to the arrangement of the person for whom the electrocardiogram is desired. The patient must be quiet, relaxed, undisturbed, since muscular tension or movements, conversation, coughing, shivering, or restlessness, interfere with the work by causing irregular motions of the string. All such motions, and any disturbance caused by irregularities of the camera or the film, can, however, be disregarded, as they differ greatly from the regular curves of the tracing.

The wet cloths which are put on the patient in making the connection should always be put on quite hot; when this is done the warmth of the body will tend to keep them at body temperature. If they are put on cold, the effect of the cold on the skin causes a resistance, and will have the effect of pulling the string of the galvanometer over to one side. This is avoided, as said, by heating the cloths.

The Use of Fresh Water for Soaking the Bandages. The usual practice is to apply bandages soaked in salt solution around the patient's limbs; but the writer has found that a very much more detailed reading is obtained when fresh water is used. The reason for this is that the action of the salt on the metal gives rise to currents which pass through the galvanometer. These currents have to be compensated for and make the reaction of the galvanometer much less sensitive to the minute currents originated in the heart. The writer has collected a great deal of material which proves the greater delicacy of reactions obtained with the use of fresh water. The accompanying illustration (Fig. 42) shows the very much finer differentiation obtained by the use of fresh water.

Effect of the Nauheim Bath on the Galvanometer Reactions. With the use of distilled water on the bandages, it is possible to pick up any muscular action of the body, even of an extremely

slight force, provided that the skin where the contacts are made is perfectly clean. This precaution eliminates the so-called skin currents, which are probably nothing more or less than the action of secretions of the skin.

Very interesting observations have been taken in five different persons, all of whom were old patients and had had records taken a number of times. Records were taken within an hour after they had had Nauheim baths. In all five of these cases no skin resistence was found; in other words, the records could have been taken absolutely without the resistance box. Although, of course, the series of five is a small one, the fact is a striking one, and suggests that there is a field for very interesting observations along this line.

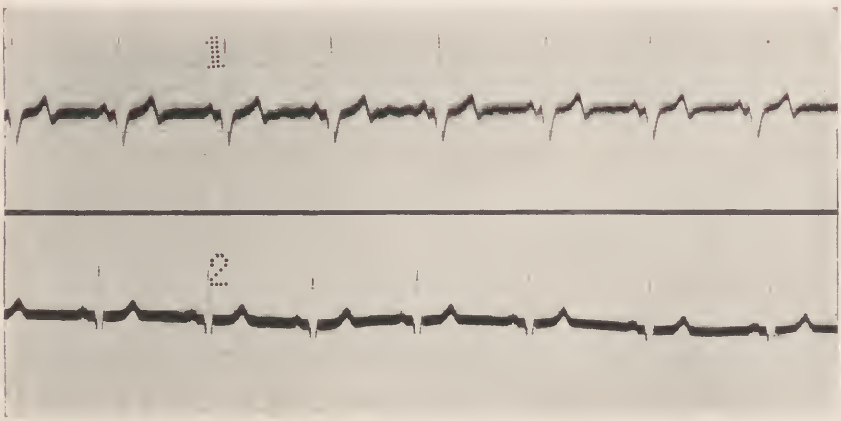

Fig. 42.—Illustrating the finer differentiation obtained by the use of fresh water in making contacts. 1, Fresh water; 2, salt solution.

Taking the Electrocardiogram. The various steps necessary for taking an electrocardiogram are as follows:

Step 1. The patient is placed in the chair, ready for examination.

Step 2. *Compensating Current.* This is one that is made use of in order to compensate the current received from the patient, and also other currents. For instance, if the patient's current is positive or negative, then current is introduced which is sufficient to bring the balance back to the center.

Step 3. *Indicator of Leads.* The Leads are marked off on an indicator. This is turned off to zero before commencing.

Step. 4. *The Magnet.* The magnet is excited. The ammeter

should read at least 2½ amperes. The operator should wait until the indicator comes to rest, as when the magnet is first excited there are vibrations of the pointer.

Step 5. *The String Galvanometer.* This is now fully connected. A dial indicates when the full connection is made.

Step 6. *Tension of the Galvanometer.* To reach a safe tension, 1 millivolt of the 1 millivolt dial is added.

Step 7. *Testing Tension.* To do this the string is loosened or tightened, until the shadow moves 1 centimeter in response to 1 millivolt of current. This is the usual standard.

Step 8. The added millivolt step, used for testing is now removed and the indicator moves back to zero.

Step 9. Disconnect the galvanometer by turning the dial to zero.

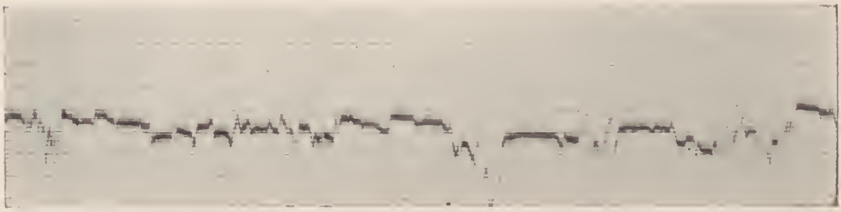

FIG. 43.—Illustrating a continuous vibration of the string which usually indicates dust on the contacts of the resistance box.

Step 10. *Connecting the Patient.* This is done through the compensation box (box holding the coils for the compensating current).

Connection of the patient for Lead I is made by currents from the right arm and left arm (current across the base of the heart).

Step 11. Reconnect galvanometer, one step. The current from the patient is put in very gently, through the protecting resistance coils; if this caution is not observed the suddenness of the current would throw the string against the magnet and break it. The resistance is reduced one step at a time, until there is nothing left but the patient's currents and compensating current.

Step 12. The current from the patient is compensated until the shadow of the string is exactly in the center.

Step 13. Gradually add more of the patient's current to the galvanometer.

Step 14. Again compensate the current from the patient until the shadow is in the center.

Step 15. There is nothing left now but the patient's currents and compensating current.

Step 16. Compensate until the shadow is in the center.

Step 17. *Tension of String.* The patient, being now fully connected, loosen or tighten the string until it moves 1 cm. to 1 millivolt of current.

Sep 18. Start film, by turning handle.

Step 19. Lead I is now taken (right arm and left arm).

Step 20. All connections are now turned off, on both the patient and the galvanometer.

Step 21. *Prepare for Lead II.* To do this, before turning in string galvanometer for Lead II, the tension should be tightened by a half turn of the wheel of the micromic screw that governs the galvanometer tension in the housing (metal casing of the galvanometer),

Step 22. Repeat Steps 5, 6, 7, 8, and 9.

Step 23. Connect the patient for Lead II (right arm and left leg). Repeat steps 11, 12, 13, 14, 15, 16, 17 and 18. Take Lead II, then repeat step 20.

Step 24. *Prepare for Lead III* taking the same steps as for Lead II. Finally turn all indicators fully off.

NOTE: *Safe Tension of the Machine.* On account of the vibrations of the earth, expansion and contraction due to atmospheric variations, extraneous movements and shaking, the tension of the string should be left in such a condition that it moves ¾ cm. when 1 millivolt is added. The machine can be safely left in this tension for weeks or months.

Magnet Switch. The batteries should be disconnected by opening the magnet switch, as soon as possible after finishing with the patient, otherwise they run down very quickly.

Difficulties and Their Reasons.

Slight Continuous Vibration of the String. When one starts to turn in the patient's currents, and a slight continuous vibration of the galvanometer string appears (Fig. 43), it is almost sure to be due to dust on the contacts of the resistance box. To remedy this, disconnect the patient, and turn the compensat-

ing resistance backwards and forwards a dozen times or so, which pushes the dust off temporarily and removes the obstruction. This is only of temporary benefit, however, and when through with the patient, it is necessary to clean the box thoroughly. The slightest sign of this vibration warns the operator that it is necessary to clean the box as described in Chapter I, paragraph 16.

Continuous Vibrations in all Leads. If continuous vibrations appear in all Leads the cause may be sought in a crystallization of the wires that run from the galvanometer housing to the control box. These should be taken out and replaced with new ones. This is not a very frequent accident, however. The crystallization is probably caused by the fact that these wires run underneath a very powerful magnet, which acts thus on the copper.

Vibration of the Floor. When one steps up to the camera a slight vibration of the floor is started, which is picked up by the galvanometer string. The operator should always wait for this vibration to subside before turning on the camera. If he does not take this precaution the first part of the Lead presents an appearance of fibrillation.

An appearance of fibrillation is also caused by any person walking across the floor while the film is being taken. One should then stop the film and wait until the vibration has subsided before starting to take the Lead again.

Any muscular movement of the patient, such as talking or coughing will pull the string out of center.

Precautions To Be Observed.

After finishing with the patient, be very sure that all the connections are turned off to zero.

Before making new connections with the patient and the galvanometer, be sure that everything has been previously turned off to zero.

Unless these precautions are strictly adhered to there will always be trouble. The most frequent mishap is that one finds the string has disappeared, and on searching for it, it is found touching the magnet (shoe of the magnet) and stuck fast to it.

If this has happened, a frequent mistake is to try to free it by tightening it, with the result that the increased tension causes the string to break.

Method of Freeing the String. Take out the wedge and with a very fine hair (a coarse one will not serve) pry the string loose. To do this it is necessary to use a magnifying glass, as the string is barely perceptible to the naked eye.

General Considerations.

Sensitiveness of the String Galvanometer. The galvanometer is extremely sensitive to currents that are passed through it, and therefore very liable to pick up outside currents such as those from radiographic wires, or those of an *x*-ray machine working anywhere in the neighborhood.

This sensitivity to vibrations is illustrated by the fact that the writer has even been able, by having a contact with the lead covering of the Lead wires on the post of the compensating box, to pick up the vibrations when an ordinary front door bell rang two floors below and set the string in vibration. Such vibrations are of a very regular character.

Vibrations that are not regular in time or force are due to vibrations of the earth, and these can be eliminated by keeping the contacts clean and avoiding loose connections.

Character of the Electrocardiographic Records. It may be asked what the electrocardiogram really represents. What the machine does, in effect, is to record the utilization of energy by the body, in any of its processes, the heart's activity being the best known and most thoroughly studied of these. This is shown in a striking way during the taking of a record of a person who has dropped to sleep in the chair while having the Leads taken. At the precise moment of time at which the individual drops asleep, there is a distinct point at which the energy is cut down, and this diminution makes itself evident in the record by the lessening of the height and force of the waves. With the shutting down of cerebral activity there is a coincident reduction in the heart's energy output.

While the recording of the heart's energy is a comparatively complete branch of study, other uses of the electrocardiograph are merely in the experimental stage, although they offer a

wonderful opening for research and experimentation. The string galvanometer has been applied to recording of the action of the brain, which is a more direct process than that applied to the heart. It can also be used in connection with intestinal muscular activity. In experiments directed toward making records of other types of energy that may be detected by this machine, better results may be gained by using very much smaller contacts than those used in electrocardiographic work. The latter have a surface measurement of about 9 square inches. Contacts applied to the temples are quite small; those applied to the abdomen in tracing movements of the colon may be larger, but it is a matter of exact experimentation to determine which size of contact procures the best result. With suitable contacts it is possible to make records of the brain or of the gastrointestinal tract which may lead to the adoption of this machine in a widely extended field of medicine.

INDEX

J B L